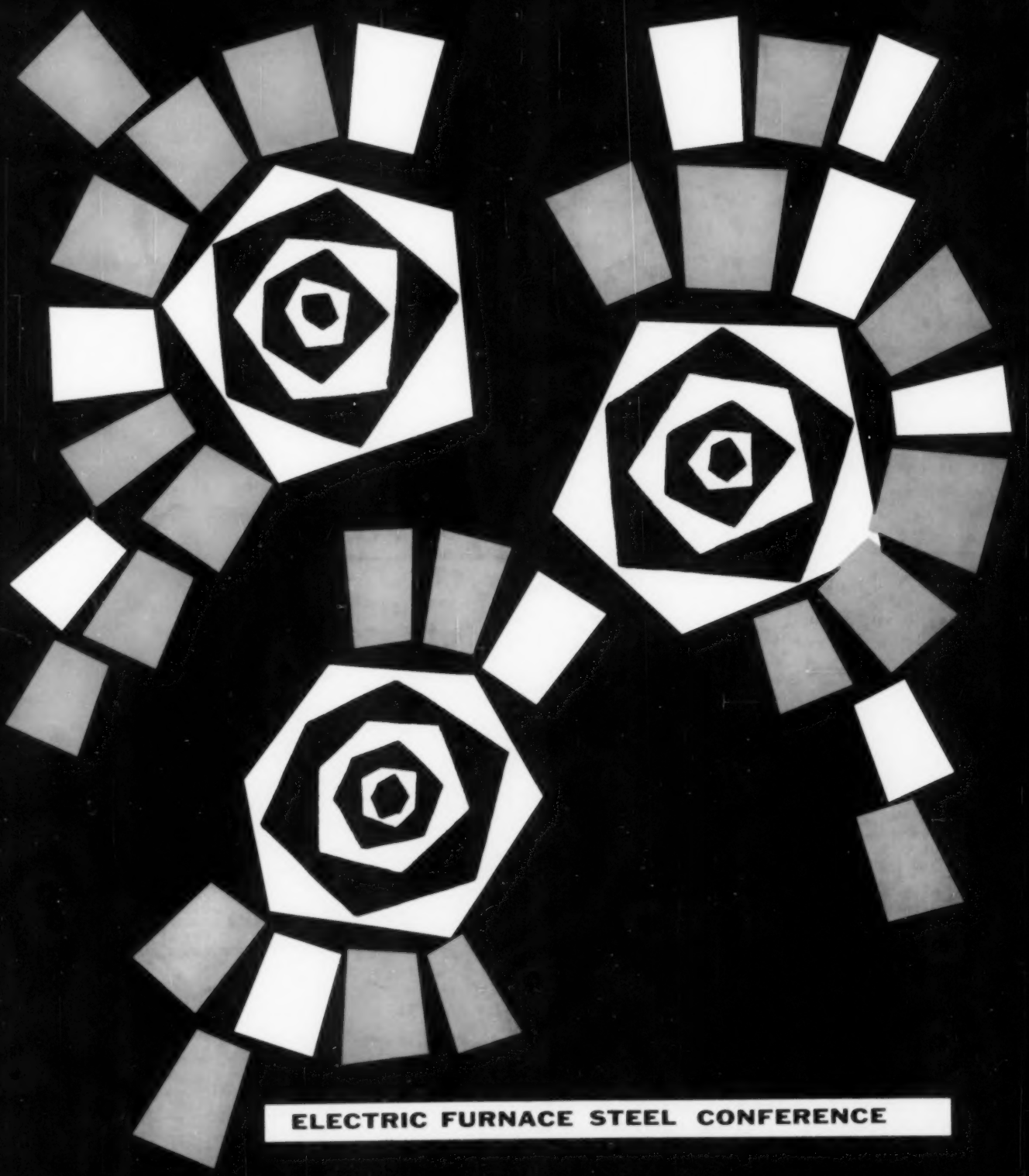
JOURNAL OF

METALS

DECEMBER 1957



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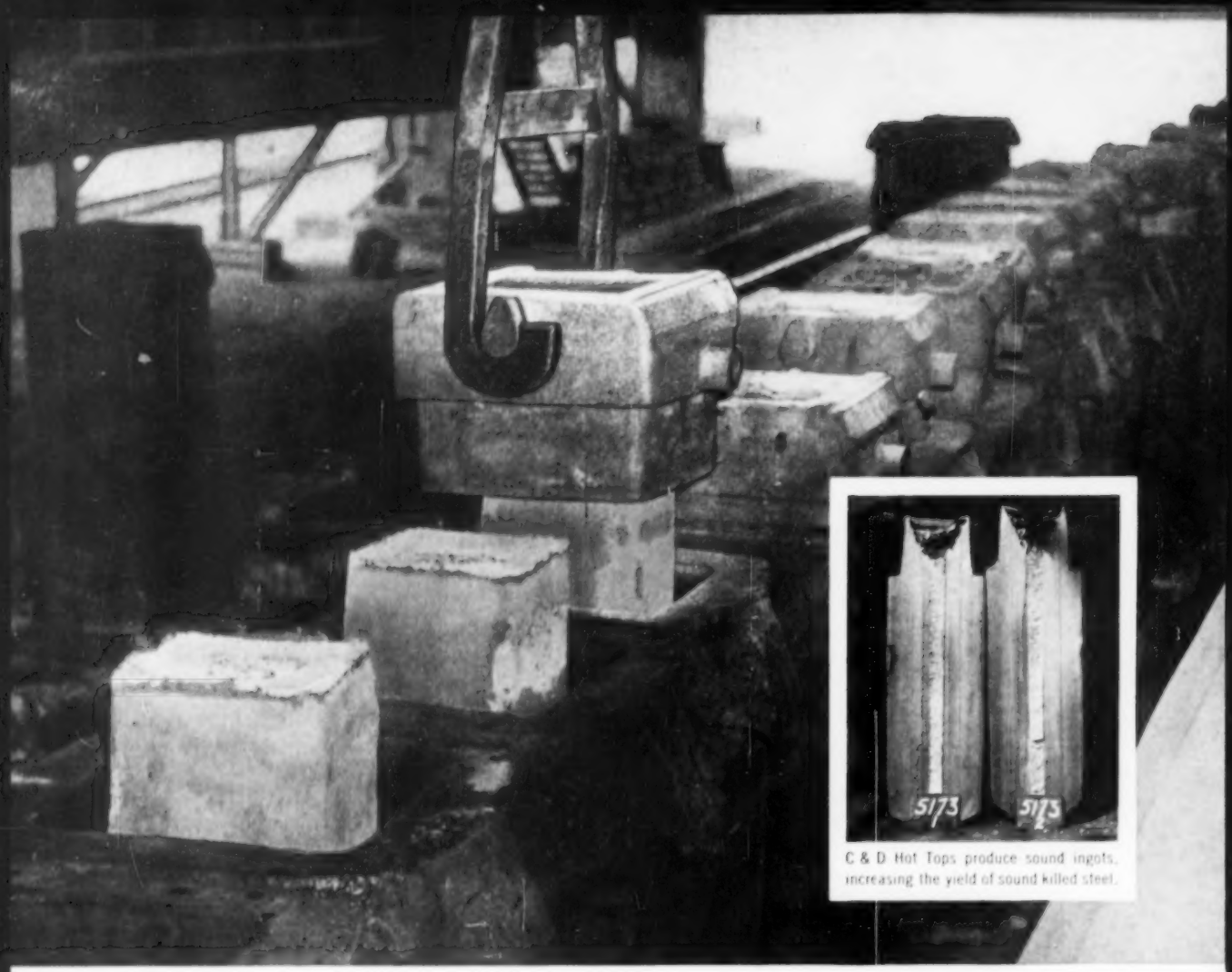

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METALS

VOL. 9, NO. 12

DECEMBER 1957

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COVER

The 15th annual Electric Furnace Conference convenes in Pittsburgh on December 4. Naomi Lazard has chosen arc furnace electrodes for this month's cover highlighting the conference. Program details are given on page 1506 and the Electric Furnace Steel Committee is shown on page 1505. Articles on steelmaking developments begin on page 1513.

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Electric Furnace Steel Conference Program **1506**

STEELMAKING ARTICLES

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Ladle Slag-Refining of Electric Furnace Steel — Rene Perrin — 1517

Cast and Rammed Arc-Furnace Roofs — J. D. McCullough — 1521

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Raw Materials for the American Iron and Steel Industry — J. C. O. Harris — 1529

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(Continued on page 1472)

Additional classified advertising appears on pages 1471 and 1475.

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An Approach to Modern Physics by E. N. da C. Andrade, Anchor Original A111, Doubleday & Co. Inc., 95¢, 1957.—The historical background and present status of modern physics, by one of the world's leading scientists.

Directory of Steel Foundries in the United States, Canada and Mexico, published by the *Steel Founders' Society of America*, 606 Terminal Tower Bldg., Cleveland, 277 pp., $15.00, 1957.—This directory lists personnel, capacity, equipment, processes employed, use of product, number of employees and also features a geographical directory with much of the basic information coded for quick reference purposes.

Proceedings of the First International Atomic Energy Conference, (Geneva, 1955), by *The Chronicle of United Nations Activities*, 234 W. 26 St., New York 1, N. Y., 16 volumes on Microcards, $70.00, 1957.—An extensive reference work containing more than 1,000 technical papers delivered at the Conference by scientists of more than 60 countries. The entire proceedings including a large number of detailed illustrations are recorded on Microcards. Among the papers submitted are: The Role of Nuclear Power, Physics, Research Reactors, Power Reactors, Geology of Uranium and Thorium, Production Technology of the Materials Used for Nuclear Energy, Radioactive Isotopes and Nuclear Radiations in Medicine, Biological Effects of Radiation, etc. The 16 volumes of the Conference represent the most important single collection of information on the peaceful uses of atomic energy that has yet been made available.

The Metallurgist, English translation of the Russian Metallurgy Journal, is now available from *Consultants Bureau*, 227 W. 17th St., New York 11, N. Y., at a yearly subscription rate of $95.00, 1957.—The Soviet Journal covers: Smelting, refining, processing, internal structure, applications of radioactive isotopes, etc., and all other phases of research from ore to finished product and applications. Tables of Contents are free upon request.

Magnetohydrodynamics, edited by Dr. Rolf K. M. Landshoff, *Stanford University Press*, 1957.—The book is an outstanding research work of 11 top U. S. and British physicists and astronomers in the new field of magnetohydrodynamics, the study of how magnetic fields influence and are influenced by ionized gases which are brought about at extremely high temperatures. Detailed in the volume are Some Dimensional Aspects of Hydromagnetic

(Continued on page 1479)

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(Continued from page 1470)

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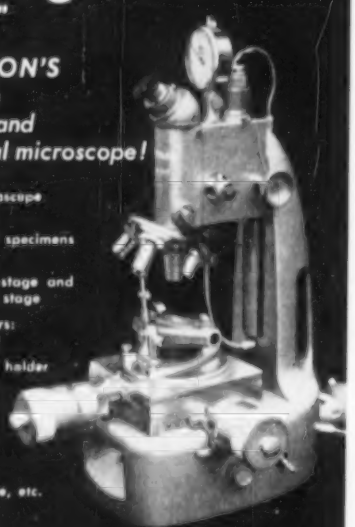

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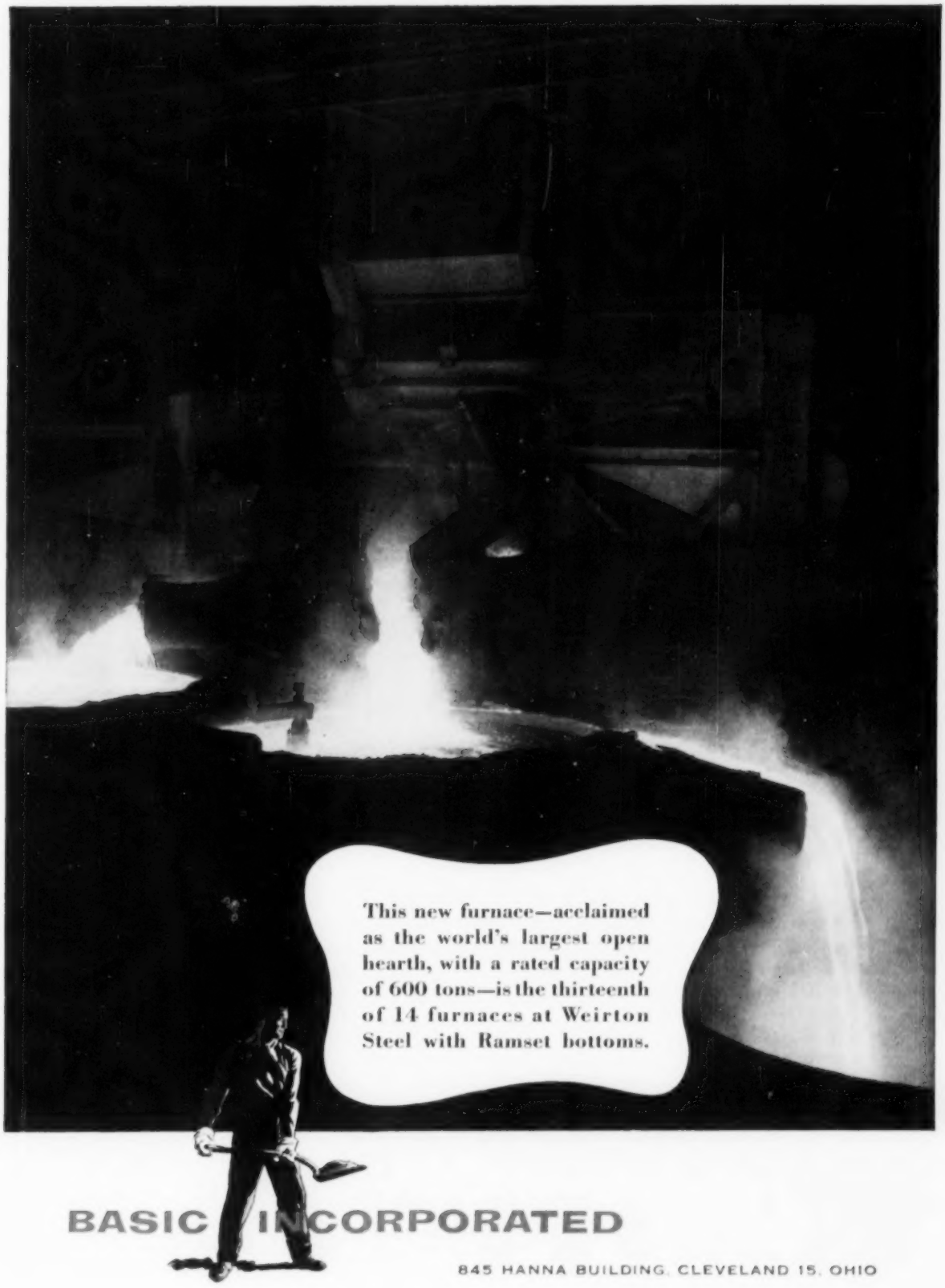
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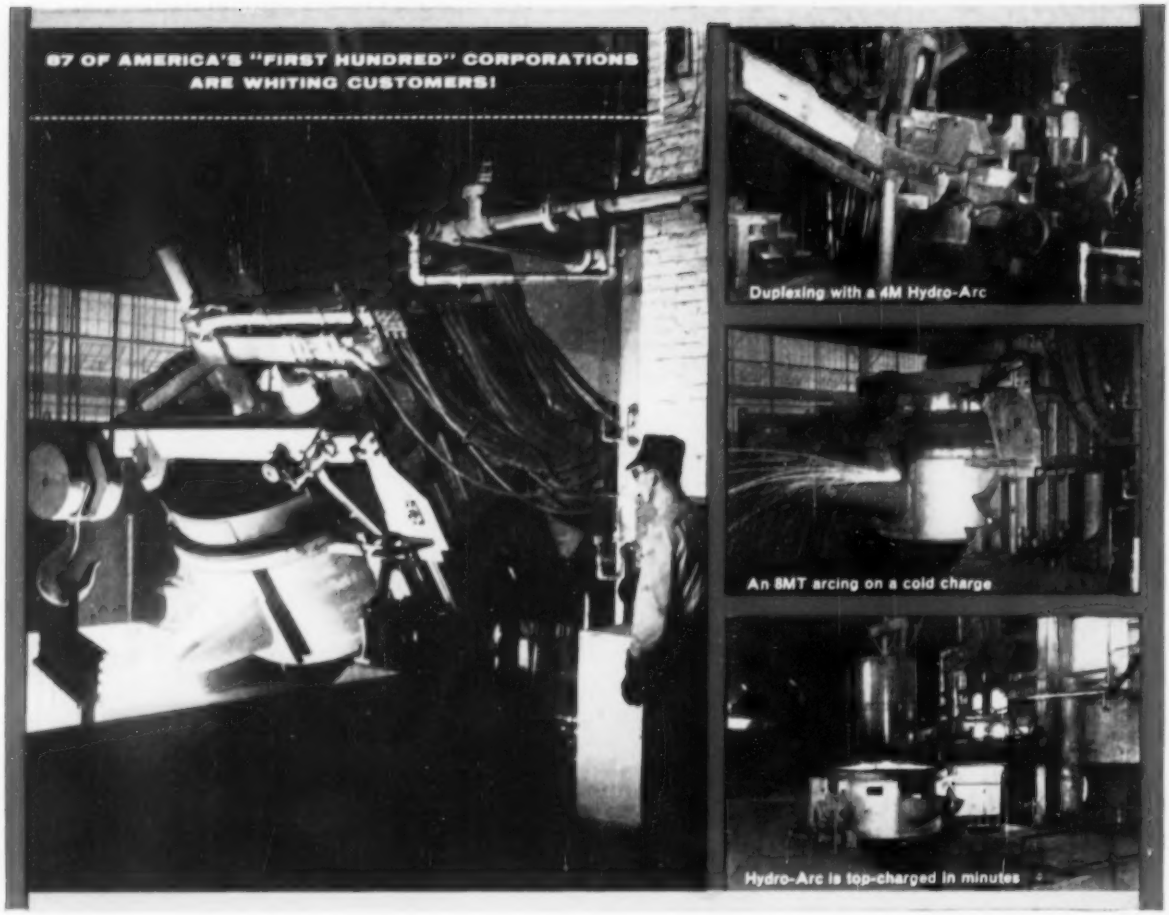
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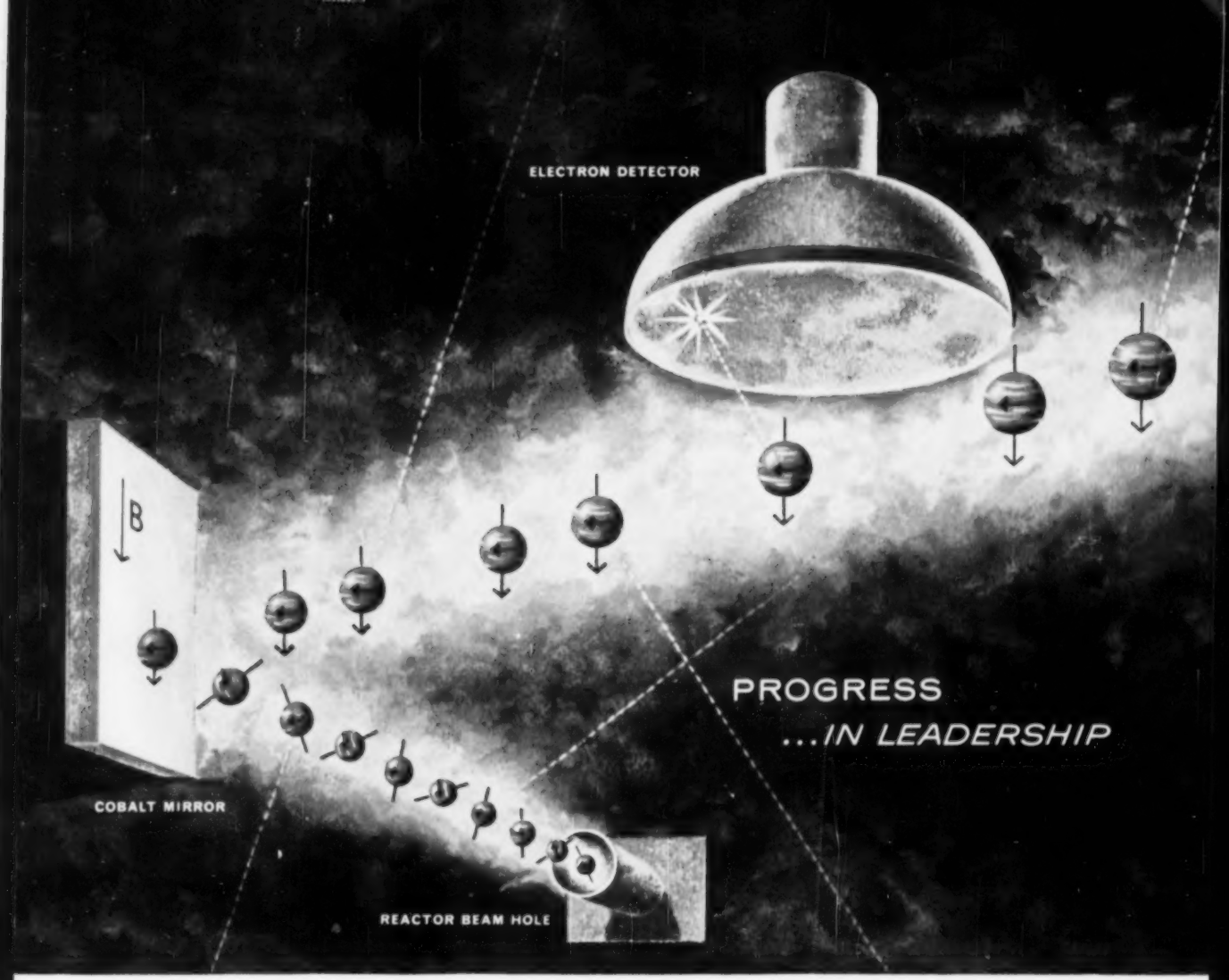

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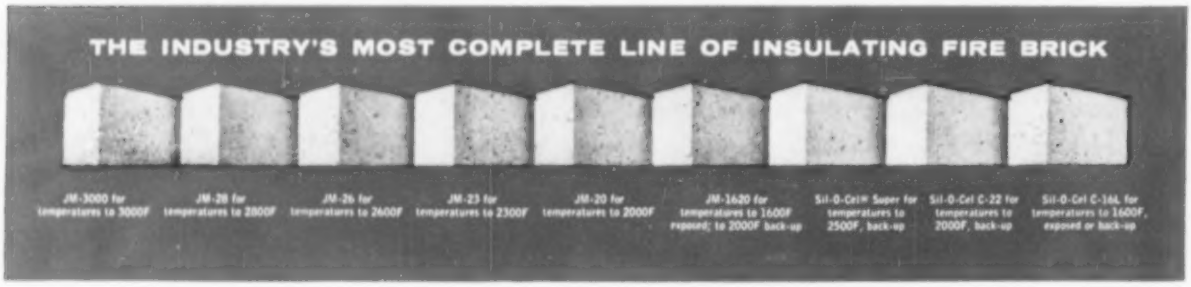
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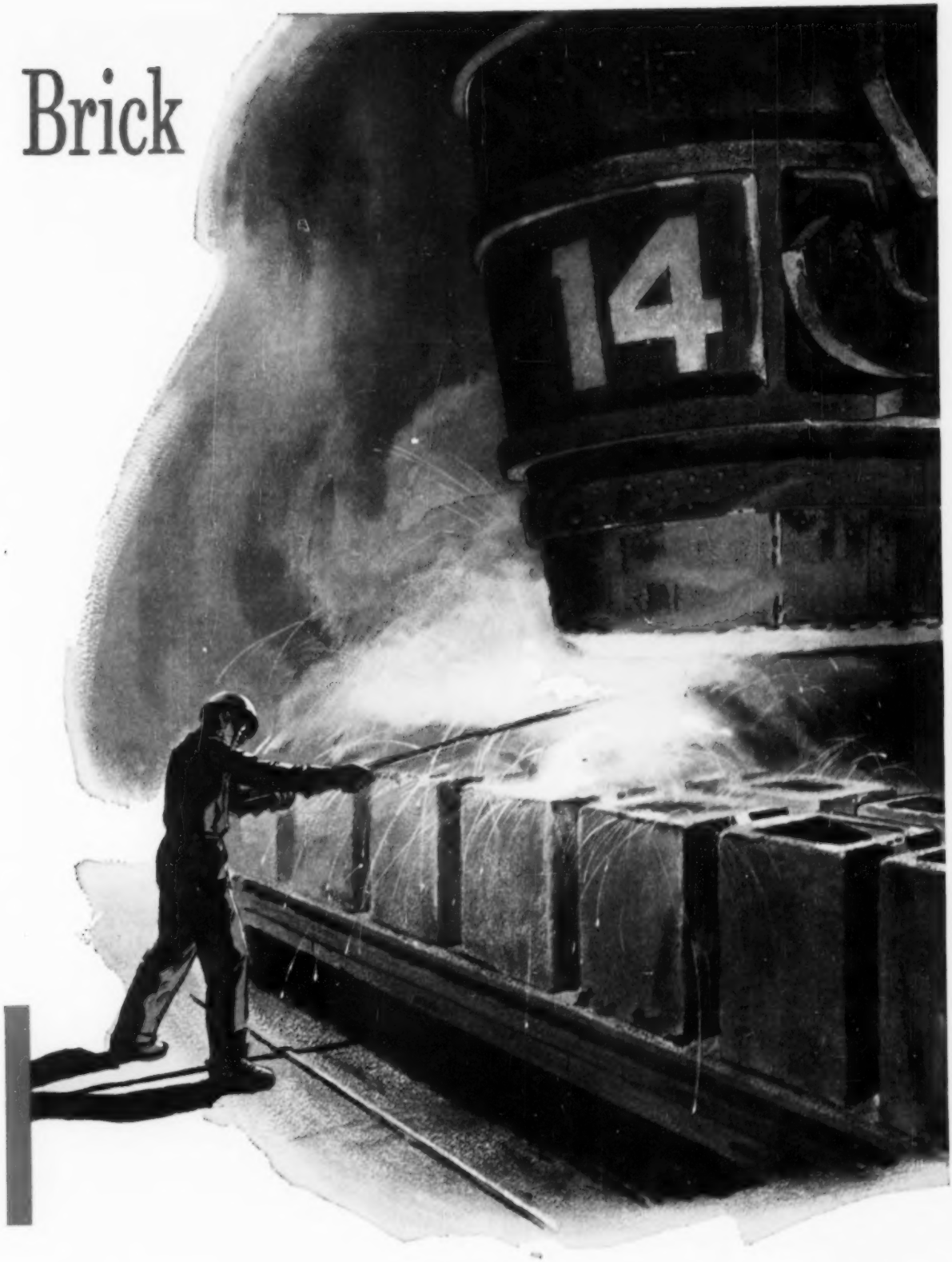

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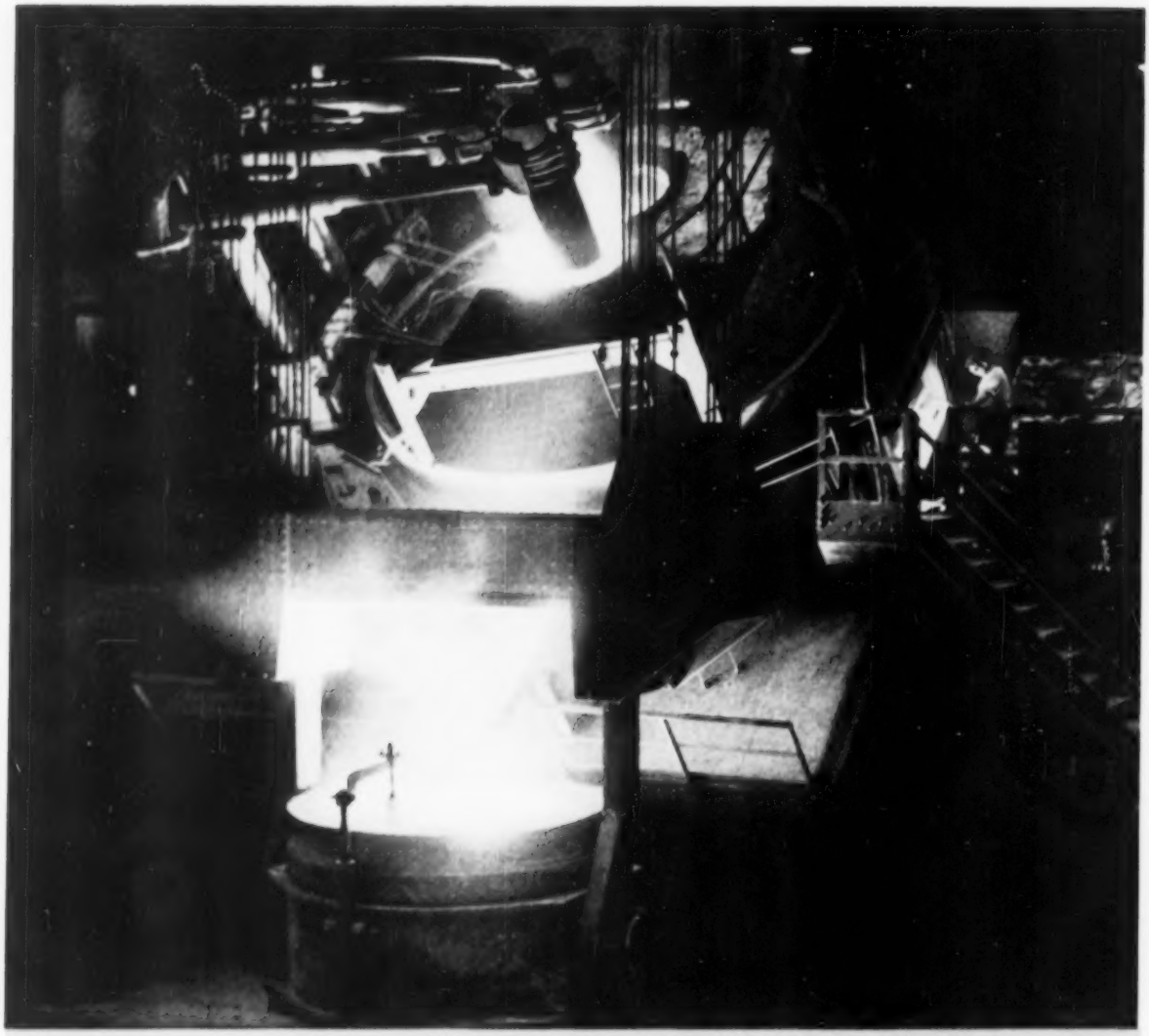

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Books

(Continued from page 1472)

Phenomena, the Build-up of Large Magnetic Fields Inside Stars, Penetration of a Shock Wave into a Magnetic Field, Dynamics of a Pinched Gas, Scaling Laws as an Aid to Experimental Studies, etc.

Nuclear-Atomic Economic Survey, published by the *Nuclear-Atomic Survey*, 101 Park Ave., New York, $5.00, 1957.—Investors and speculators are warned to cautiously approach the so-called high-energy "exotic" fuels and new high-temperature metals by the Surveys special research project report. The Survey reviews the profit and loss prospects in securities representing titanium, columbium, rare earths, boron, uranium and thorium.

Nuclear Notes For Industry has been terminated. Information on AEC unclassified technical reports of the type formerly covered in this publication should consult **Nuclear Science Abstracts,** issued bi-monthly by the Atomic Energy Commission. NSA is available on subscription at $7.50 per year from the Superintendent of Documents, *U. S. Govt. Printing Office*, Wash. 25, D. C.

Solid State Physics: Advances in Research and Applications, Vol. IV, edited by Frederick Seitz and David Turnbull, *Academic Press Inc.*, 111 Fifth Ave., New York, $12.50, 1957.—This volume covers Ferroelectrics and antiferroelectrics, Orthogonalized plane-wave methods, bibliography of atomic wave functions, techniques of zone melting and crystal growing and Theory of Mobility of electrons in solids. In view of the rapidly increasing research activity in the field of solid state physics, the editors are continuing the initial policy of publishing two volumes a year for sometime longer. •

Thermal Stresses: by B. E. Gatewood, *McGraw-Hill*, 232 pp., $7.50, 1957.—Directed especially to the engineer and the aeronautical engineer, this is the first book on thermal stresses to cover all phases of the design problem of elevated temperatures. The author's purpose is to give basic information for attacking the problems of thermal stress, and to indicate possible procedures for solving those associated particularly with elevated temperatures in airplane and missile structures, turbines, and nuclear reactors. •

The Solidification of Castings: 2nd Edition, Institute of Metals Monograph and Report Series No. 7, by R. W. Ruddle, *The Institute of Metals*, 4 Grosvenor Gardens, London, S. W. 1, England, $6.50, 1957.—Completely revised and almost four times longer, the present volume critically summarizes the researches that have been carried out into so-

(Continued on page 1482)

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"The outfit with the 'know how' has the answers"... and this is doubly true in Vacuum technology! KINNEY High Vacuum Pumps provided the answers "away back when" and you can practically chart the significant advances in Vacuum processing by the developments contributed to the art by KINNEY engineering.

The KINNEY oil sealed rotating plunger Pump, producing pressures down to 0.2 micron, continues to be the outstanding Pump of its kind in the world. The KINNEY Mechanical Booster Pump, introduced but four years ago, is contributing important advantages in securing clean, dry Vacuum at even lower pressures.

Now KINNEY offers the metallurgist new tools for production and research...complete High Vacuum Systems – Evaporators, Furnaces, Drying Ovens and Packaged Pumping Systems. And for the Metals industry – Complete High Vacuum Systems for Melting, Degassing, Casting, Refining and Heat Treatment.

Yes, "for new developments in Vacuum Metallurgical Equipment" get the answers – *based on experience* – from KINNEY.

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2500 pound ingot of titanium cast in a single mold using ti sponge as the consumable electrode

NOW

melt buttons, pounds, or tons in proved vacuum arc furnaces

W. C. Heraeus of Hanau, Germany, have made and operated more than 100 of these vacuum arc furnaces over a ten-year span.

Now you can share the mastery of vacuum melting and casting gained through this broad experience. The furnaces are for sale on a royalty-free basis. Included are complete information and thorough training in proved techniques—all with no strings attached.

You can now produce melts in vacuum or a controlled atmosphere—in ingots up to 24" diameter and larger—of steel, zirconium, titanium, and high melting point alloys. You can produce melts of very high purity and superior grain structure; for example: titanium with hydrogen levels held to 0.0012 wt.% and Brinell hardness values between 95 and 105.

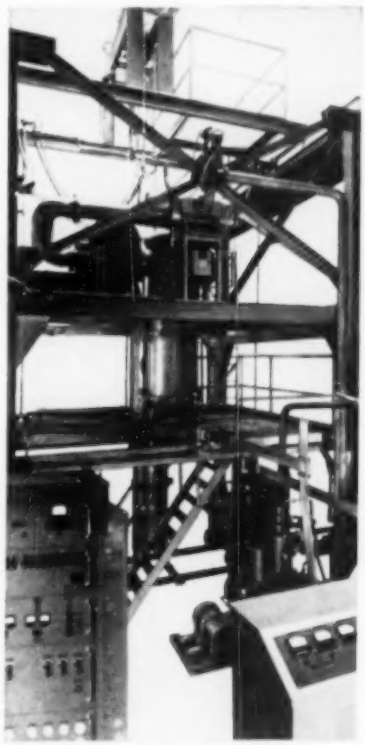
Unique electrode feed. The high quality of the melts is attained by feeding the consumable* electrodes at optimum rates. An electronic system, the Heratron Control, monitors arc voltage, current, and short circuits—and automatically maintains the arc between $\frac{1}{2}$ and 1 inch in length.

Maintaining the vacuum. Each pumping system is assembled from the world's largest selection of CEC vapor pumps, Roots pumps, and other mechanical pumps. Whether your specifications call for a diffusion-ejector pump plus a Roots pump or a Roots pump plus another mechanical pump, CEC can provide the very finest together with the necessary vacuum controls, gauges, valves, and piping.

How to purchase. There are five standard models of the Heraeus furnace with capacities from 20 lbs. to 6600 lbs. of steel—and special designs with capacities ranging up to and beyond 10,000 lbs. of steel.

CEC has an exclusive license to sell and service these furnaces, the Roots pumps, and accessories. For a complete discussion of these proved furnaces, write for Bulletin 4-27.

*The smallest of these furnaces also operate with non-consumable electrodes



Ingots of 16" diameter can be processed in this Model VA-L 600 sh Heraeus furnace.

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Rochester Division, Rochester 3, N. Y.

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The Morgan-Isley system offers you a better means of heating ingots with straight blast furnace gas, coke oven gas, natural gas or oil.

The schematic shows the flow of combustion air and flue gases through the regenerators and soaking pit. The Morgan-Isley system employs vertical regenerators. It eliminates regenerator capacity under the crane runway thus freeing this valuable area for heating steel.

CCC-49

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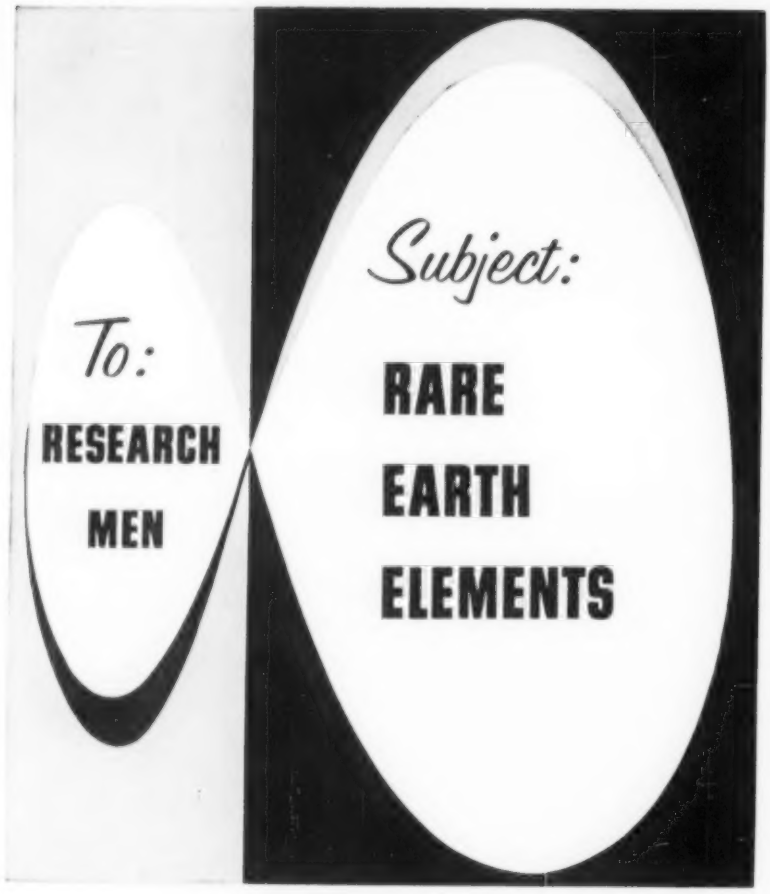

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Books

(Continued from page 1479)

lidification and presents the results to the reader in a readily assimilable form. The book is intended primarily for the research worker and advanced foundry technologist, but much of it will be of great interest to the practical foundryman.

Behaviour of Metals at Elevated Temperatures: published by *Philosophical Library Inc.*, 15 E. 40th St., New York 16, N. Y., 122 pp., $6.00, 1957.—The volume covers the effect of temperatures from only slightly above normal up to the highest working limits. These papers contain the latest information on a number of subjects such as: the effect of temperatures up to 450°C, with particular reference to airframe structures and guided missiles, the effects of temperatures of 500°C upwards on non-ferrous metals and the effect of high temperatures on the engineering properties of metals. Included in the text are 63 diagrams and 3-pages of art plates. •

U. S. Research Reactors: *Office of Technical Services*, U. S. Dept. of Commerce, Wash. 25, D. C., 73 pp., $1.50, 1957.—The paper bound book, released by the U. S. Atomic Energy Commission, is illustrated with 116 drawings, photos, diagrams, and charts, describing more than 30 research reactors, now in operation or under construction. The booklet includes some cost information and has a brief glossary of reactor terms.

Recommended Practice for Repair Welding and Fabrication Welding of Steel Castings: published by the *Steel Founders' Society of America*, 606 Terminal Tower Bldg., Cleveland, 50¢, 1957.—Replacing an earlier publication first issued by the society in 1951, the new manual features what is probably the most comprehensive listing of the American Welding Society Classified Mild Steel and Low Alloy Electrodes Published to date. The three sections of the manual cover welding methods, electrodes and recommended welding procedures for carbon steel and low alloy castings with each general alloy series indexed for quick reference.

Précis De Magnétoscopie, by E. A. W. Müller, *Dunod*, Paris, France. 169 pp., $5.50, 1957.—A French translation of steel (flaw detection). The three chapters cover demagnetisation, economic considerations, and literature references.

Précis De Métallographie Appliquée, by A. Roos, *Dunod*, Paris, France. 381 pp., $12.00, 1957.—This outline of applied metallography begins with a general discussion of crystal structure. The general characteristics of binary alloys are discussed, leading

(Continued on page 1486)

4 *big reasons why you should specify...*

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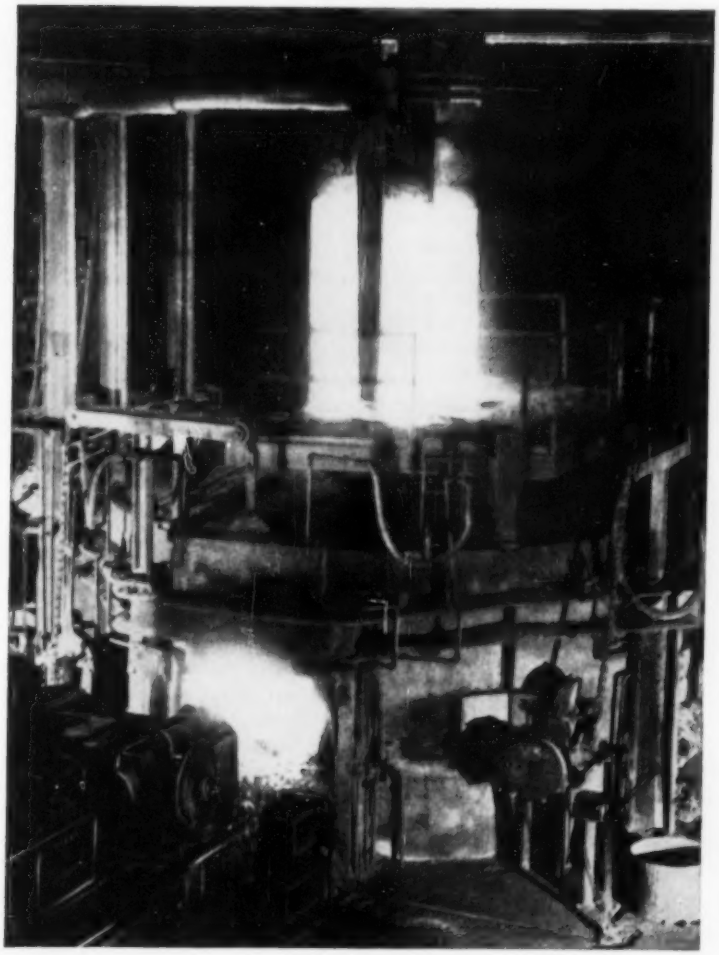

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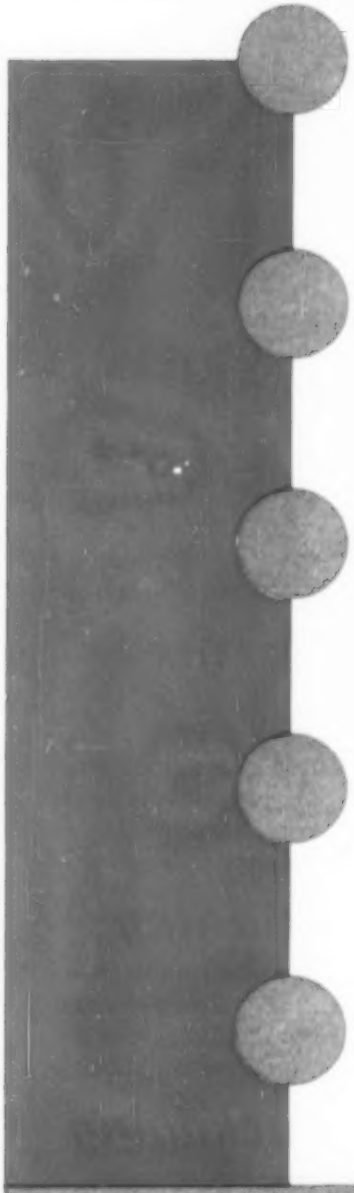
60 CYCLE INDUCTION MELTING



A famous metallurgist once wrote: "50% of all rejects can be traced to faulty melting and pouring." When molten metal is overheated, important alloy ingredients are lost by burning. Castings or billets may be porous from combustion gases absorbed by the molten metal. Frequently, unwanted alloy ingredients are picked up from the containers used in melting. If the temperature of molten metal flowing into a mold strays from the optimum, defective castings will result. In a quiet melt alloy ingredients may not dissolve properly, and the metal cast will not meet specifications. Finally, there is the problem of nonmetallics suspended in the melt which cause occlusions and other difficulties in the end product.

60 CYCLE INDUCTION MELTING, properly applied, is probably the biggest single step that can be taken to overcome these traditional melting problems. The method is unique in its combination of two factors: Heat is generated only in the molten metal, and the entire melt is stirred by electromagnetic pressure. Furthermore, high melting rates can be concentrated in a small space. —No part of the furnace is hotter than the metal. Combustion gases are absent and controlled atmospheres can be used. The container is constructed of refractories inert to the molten metal. Temperature control of unprecedented precision is inherent in the method. Electromagnetic stirring assures complete dissolving of all ingredients and a uniform alloy. Suspended nonmetallics are deposited in the electromagnetic pressure area.

These are basic reasons why 60 CYCLE INDUCTION MELTING has had such a spectacular growth in the postwar period. Modern plants require high production rates with controlled quality, yet can assign only a minimum of skilled labor to each operation. 60 CYCLE INDUCTION MELTING minimizes hard labor in melting. It enables process control to substantially decrease the effect of human error. Cost reductions are reflected throughout each step of fabrication of a casting or billet to its end use.

60 CYCLE INDUCTION MELTING, firmly established for thirty years as the predominant production method for melting brass, has recently been applied on a much larger scale. In the last ten years, as new furnace designs became available, the method has been rapidly adopted by many progressive companies in the fields of aluminum die casting, aluminum extrusion, aluminum wire, aluminum coating, leaded copper alloy casting, zinc die casting, and galvanizing of strip in the steel mills. Well over one thousand 60 CYCLE INDUCTION MELTING furnaces are now operating in these new fields.

Our 60 CYCLE INDUCTION MELTING furnace takes many different forms to meet the needs of all these industries. Unit production rates now range from 150 pounds to 40 tons per hour. We specialize in the development, design, and manufacture of standard and custom-built furnaces to meet each requirement. If there is a production melting problem in your operation which may benefit from a basic change in method, we should be glad to discuss the possibilities with you

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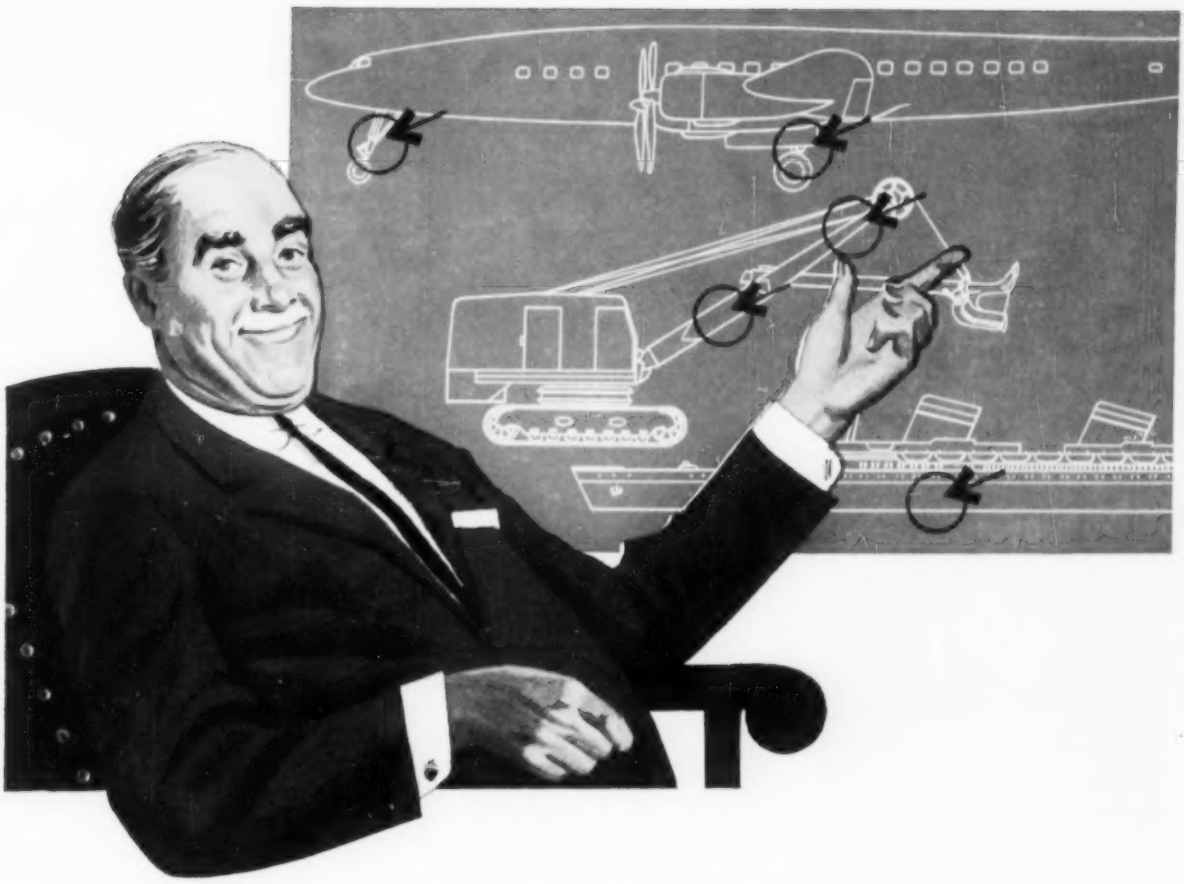

Columbium and you, the steelmaker

Know how .10 Cb will increase physical properties?

Know how Cb will benefit high temperature steels?

Extensive test and development work by MCA has recently revealed astonishing results in the use of columbium in steel making. Particularly in constructional steels—those used in road machinery, airplane landing gear, and plates for example, where the impact stress is severe—progress in physical properties has been most striking.

In some cases steels with economical additions of columbium may avoid the necessity of heat treating and be used in the as-rolled condition. In other applications tensile strength may be increased many thousands of pounds per square inch. Significantly, steelmaker's economics justifies the use of columbium, in these steels, since the results obtained are most rewarding for the small cost of columbium additions. We confidently expect even greater progress as the developmental knowledge in this new field increases.

We are anxious that steelmakers, engineers and metallurgists know of the latest progress in this field. An inquiry on your company letterhead stating your particular interests will bring confidential and prompt response. Write today.

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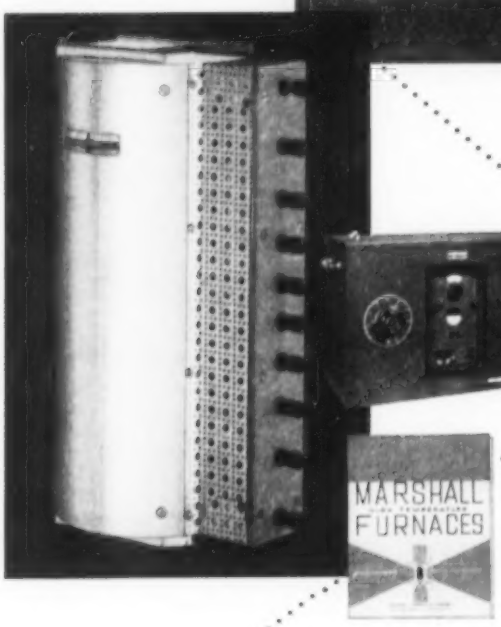

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up to 2600° F.

Marshall's tubular, shunt-type laboratory furnaces are compactly designed to apply electrical heat up to 2600° F. under exact control. They are widely used as components of machines for tensile, stress-rupture and fatigue testing of metals, ceramics and cermets; also for creep testing metallic alloys.

uniform temperature distribution

Marshall's control panel regulates the amount of heat developed in the whole unit. Accurately spaced, properly anchored furnace coils maintain uniform temperature distribution. Test duration may range from moments to 10,000 or more hours.

rigid zone control to ± 3° F.

Rigid control to ± 3° F. at any point inside the furnace is easily achieved. Many experienced operators of Marshall furnaces report temperature can be held to ± 1° F. Shunted resistances, co-ordinated with the control panel, provide the extremely accurate zone-by-zone temperature control. Standard models are available with inside diameters from 1" to 6" or more, and from 12½" to several feet long. Custom models are developed to meet special needs.

MARSHALL PRODUCTS CO.
tubular furnaces and control panels

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Books

(Continued from page 1482)

to a consideration of phase diagrams and particularly the iron-carbon diagram. The book ends with a brief treatment of research methods in the field.

Titanium, *F. S. Smithers & Co.*, 1 Wall St., New York 5, N. Y. 100 pp., $5.00, 1957.—A condensed presentation of the sources and availability, processing methods, production economics, utilization and markets for titanium. There are also reviews of the activity of individual companies in the titanium field and other miscellaneous statistics.

Fatigue Durability of Carburized Steel, published by *The American Society for Metals*, 7301 Euclid Avenue, Cleveland 3, Ohio. 123 pp., $4.00, 1957.—A group of three papers as follows: effect of surface condition on the fatigue resistance of hardened steel; summarized results of an extensive series of tests on fatigue durability of carburized steels. A summary of the overall research is included and there is a bibliography.

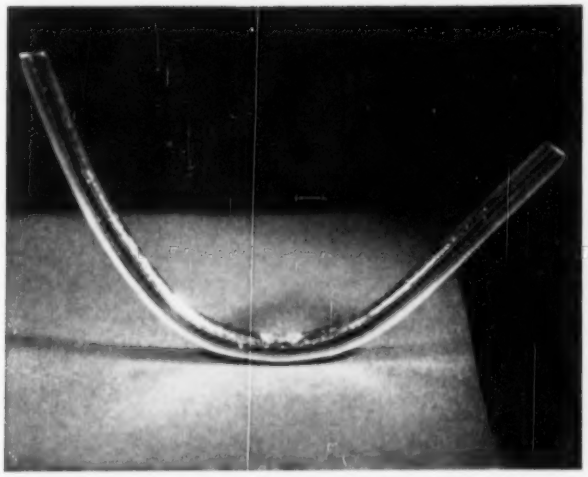
Brittle Behavior of Engineering Structures, by Earl R. Parker, *John Wiley & Sons Inc.*, 323 pp., $6.00, 1957.—This volume summarizes the available information on: fundamental properties and fracture theories; test methods and interpretation of results; influence of chemical composition and manufacturing practice; effects of welding composition variations; residual stresses; design aspects; and reports on individual service failures. •

Principles of the Properties of Materials by Jacob Porter Frankel, *McGraw-Hill Book Co. Inc.*, 221 pp., $6.00, 1957.—Principles and properties are emphasized rather than materials in this new study of the properties of materials. The book, which is intended as an introduction to all fields of engineering, is based on a series of lecture notes prepared for sophomore classes in the properties of materials at the Northwestern Technological Institute. •

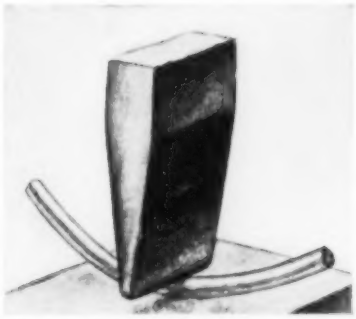
Thermodynamics for Chemical Engineers 2nd edition by Harold C. Weber and Herman P. Meissner, *John Wiley & Sons, Inc.*, 497 pp., $8.50, 1957.—This second edition is a comprehensive coverage of the principles and applications of thermodynamics from the viewpoint of both the engineer and the chemist. The book includes an expanded treatment of fluid flow, plus descriptive chapters on power cycles, engines, turbines, and refrigerators. This new edition contains many illustrative examples with solutions and more new problems designed to make the reader think rather than calculate. •

(Continued on page 1490)

Thermo-compression bonding—



Wire bonded to germanium by thermo-compression technique (enlarged). Wires only 1/10 the breadth of a human hair have been successfully anchored to germanium wafers only three hairs thick. The bond may be an ohmic contact or rectifying contact by adding suitable impurities to the wire and the semiconductor.



One method of thermo-compression bonding. A heated wedge presses a wire against a heated semiconductor with enough force to deform the wire. Adhesion occurs in seconds.

new way to join metal to semiconductors

Thermo-compression bonding provides a new way to attach a wire to a semiconductor. It calls for heat and pressure—nothing else. The wire and the semiconductor are moderately heated, then pressed together under moderate pressure. The resulting bond is very strong—stronger actually than the wire. No chemical flux or molten metal is required.

Eliminating molten metal provides an enormous advantage in fixing electrical connections to transistors. That's because molten metal tends to spatter and spread uncontrollably over the surface of a semiconductor. And it may alloy with the semiconductor to alter its all-important crystalline structure and chemical purity. Thermo-compression bonding easily and quickly makes a strong permanent electrical connection without damaging the semiconductor. Furthermore, the lead may be attached to microscopic areas and precisely positioned, a most valuable aid in the construction of high-frequency transistors.

Thermo-compression bonding will speed the production of transistors . . . the transistors needed to fill all the new jobs Bell Laboratories finds for them in the quest to provide still better telephone service to our growing country.

At Bell Labs Howard Christensen and Orson Anderson discuss their discovery of new bonding principle with Peter Andreatch, Jr., who collaborated in the studies.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

Relieves traffic congestion. To handle the ten million cars a year which now funnel onto the 3-lane Carquinez Bridge, (right) the State of California is building this second bridge connecting the San Francisco Bay area and the Sacramento Valley. Use of nickel-containing USS "T-1" Steel in critical truss members has simplified design...reduced unnecessary weight...saved money.

A tale of two bridges ...and an $800,000 saving

Twins? *Almost.*

But there are two differences. The span on the right is 30 years old. Her sister is brand new.

Another big difference is in their construction materials. The most highly stressed truss members of the new bridge are USS "T-1" Steel . . . a high yield strength constructional alloy steel containing nickel.

"T-1"*, produced by United States Steel Corporation, has nearly three times the yield strength of structural carbon steel. It is at least four times as resistant to atmospheric corrosion. And it can be welded with relative ease.

It reduces weight and simplifies design.

According to computations by the State of California, "T-1" Steel will save approximately $800,000 in construction costs.

Are *you* looking *for* weight saving . . . added corrosion resistance . . . dependable strength? A nickel alloyed steel may be just what's needed to improve whatever you're making or building. Let us help you find out. Here at Inco, you can get counsel and data based on years of specialized experience with alloys containing nickel.

* "T-1" is a registered trademark of United States Steel Corporation. "T-1" Steel is produced by United States Steel Corporation and its licensee, the Lukens Steel Company.

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NICKEL ALLOYS PERFORM BETTER, LONGER

Consumable-Electrode Vacuum Remelting Furnaces

Allegheny Ludlum Steel Corp. has recently put in operation at Watervliet, N. Y., what is probably the largest furnace for melting high-purity superalloys under vacuum. This new consumable-electrode vacuum remelting furnace is capable of producing 26-in. diam ingots weighing up to 12,000 lb—believed to be the heaviest ingots produced by any vacuum melting process. This furnace brings the plant's capacity for producing the supermetals to 2 million ingot lb monthly. Further details on vacuum melting are found on p. 1513

. . . and Another

The first billets of Mid-Vac steel, made by the new consumable-electrode vacuum remelting furnaces at Midvale-Heppenstall Co. in Philadelphia, were shipped in recent weeks. The furnace produces ingots up to 20-in. diam, weighing 8000 lb.

Induction, Vacuum Furnace Installations

A large induction, vacuum melting furnace is in the final stages of installation at the Minerva, Ohio, works of Kolcast Industries Inc., affiliate of Thompson Products Inc. The furnace will be capable of melting 350-lb heats. . . Consolidated Electrodynamics Corp. has put into operation a similar furnace for melting 300-lb heats.

. . . for Reactive Metals Research

At Watertown Arsenal in Massachusetts, investigations on titanium, other reactive metals, and new guided-missile metals will be carried out with the help of a new 500-lb capacity vacuum induction furnace built by F. J. Stokes Corp.

. . . for First Commercial-Scale Pure Beryllium

At Hazelton, Pa., The Beryllium Corp. is placing in operation a Stokes induction, vacuum melting furnace for what is reported to be the first commercial-scale production of pure beryllium for nuclear reactors. The furnace has a crucible with a capacity for 120 lb of beryllium. Crude metal, in the form of shot, is charged into the crucible. After being melted and refined under a pressure of about 10μ, the +99 pct Be is poured into ingot molds. As many as five molds, 13-in. OD by 24-in. high, can be accommodated on a water-cooled rotating turntable, 36-in. in diam, which is housed within the vacuum chamber.

Vacuum Casting Progress

At U.S. Steel Corp.'s Duquesne Works in Pennsylvania, large commercial castings are now being produced by a vacuum casting method. The vacuum casting chamber consists of a cylinder 17 ft in diam and 30 ft high, in which ingots up to 95-in. diam and weighing 360,000 lb may be cast. Inspection of the ladle stream within the chamber is carried out by means of a closed-circuit television hook-up. When the television indicates that the ingot is completely poured, the vacuum in the chamber can be broken, and the ingot can be removed. It takes at least 2 days to cool the ingot before it can be further processed. Preliminary tests indicate that these castings, which are processed into large turbine and generator shafts, are superior in quality to those produced by conventional methods.

. . . and, from the staff of Journal of Metals

The Very Best Wishes For The Holiday Season

REPORTER

Books

(Continued from page 1486)

Gas Turbine Materials by G. Lucas and J. F. Pollock, *Temple Press Ltd.*, Bowling Green Lane, London, England, 158 pp., $3.60, 1957.—In this survey of high temperature materials and their application to the gas turbine, the authors show how material requirements arising from operating conditions in the gas turbine are being met by the current range of alloys.

Metallurgical Progress, Vol. 3, *Philosophical Library Inc.*, 15 E. 40th St., New York 16, N. Y., $6.00, 1957.—The third in a series, this book is a comprehensive review of the most recent research developments in refractories, coke, nondestructive testing, and the varied field of foundry technology, summarizing the present state of scientific knowledge in these vital areas of modern iron and steel metallurgy. •

Engineering Metallurgy, by the Committee on Metallurgy, *Pitman Publishing Corp.*, 2 W. 45 St., New York 19, N. Y., 516 pp., $7.80, 1957.—This is a concise, up-to-date, and authoritative presentation of the essentials of the subject, useful to all engineers, student and practicing. The book deals with general principles as related to engineering, with nonferrous metals, and with iron and steel. Machinability, corrosion, and the effects of temperature are also covered. The text is liberally illustrated with photos and drawings, and sets of exercises and problems are provided at the end of each chapter.

The Achema Yearbook 1956/1958, European Catalog of Chemical Plant, English edition, *Deutsche Gesellschaft fuer Chemisches Apparatewesen*, Frankfort, (Main), Germany, 1070 pp., 1957.—The yearbook is designed to prepare visitors to the ACHEMA Congress organized by DECHEMA, from May 31 to June 8, 1958, at Frankfort, Germany. The reference book gives information on 65 European technical colleges which are actively engaged in the field of chemical engineering, process technology, and industrial chemistry. Included are particulars of the sources of supply of 7500 types of equipment for chemical science and technology. The yearbook, which is being sent free of charge to all who have registered their names as visitors to the Congress, will be available for sale after the Congress has taken place.

Fasteners Handbook by Julius Soled, *Reinhold Publishing Corp.*, 438 pp., $12.50, 1957.—The handbook provides ready up-to-date answers to fastener problems in all fields. Pertinent data with illustrations and full page descriptions, supply detailed information on currently available fasteners. Included are typical applications, cost saving features of available but less-known fasteners, and related fastener use in one industry to another. •

Elements of Heat Transfer, 3rd Ed., by Max Jakob and George A. Hawkins, *John Wiley & Sons Inc.*, 317 pp., $6.75, 1957.—The new edition incorporates the latest techniques and trends in engineering education. Newer material added includes: a table on thermal conductivity of liquid metals, a section on the use of equivalent circuits for the solution of heat transfer problems, additional material for the analysis of engineering systems, and a chapter on mass transfer which discusses the similarity between heat and mass transfer. •

The Handbook of Radiochemical Analysis, by L. J. Beaufait, Jr., and H. R. Lukens, Jr., for *U. S. Office of Technical Services*, is now available from Tracerlabs Inc., Western Div., 2030 Wright Ave., Richmond, Calif.; the book is in two volumes: Vol. 1, **Radiochemical Techniques,** 152 pp., $4.00, and Vol. 2, **Radiochemical Procedures,** 129 pp., $3.25.—The handbook deals with radiochemical analysis of fission and nonfission products, resulting from work done under government contract by Tracerlab.

Pressure Measurement in Vacuum Systems by J. H. Leck, *The Institute of Physics*, 47 Belgrave Square, London S.W. 1, England, 141 pp., $4.50, 1957.—A comprehensive book giving a detailed treatment of the measurement of pressure. The material is presented in six independent chapters, the first five of which describe the different methods of pressure measurement in common use; gages of primarily historic interest such as the viscosity manometer, have not been considered. The final chapter is devoted to gage calibration.

U. S. Department of Commerce Publications

Request publications from:

Office of Technical Services
U. S. Dept. of Commerce
Washington 25, D. C.

PB 131104 *True Stress vs Elongation Recorder*, by D. E. Driscoll and T. S. DeSisto, Watertown Arsenal Laboratory, U. S. Army, 75¢, 22 pp., 1955.

PB 131111 *An Electronic Signaller to Reduce Quench-Cracking of Steel*, by L. D. Jaffe, D. C. Buffum, and I. L. Preble, Watertown Arsenal Laboratory, U. S. Army, $1.00, 38 pp., 1952.

MITG-246 *Lyometallurgical Treatment of Sulfated Carnotites and Other Ores*, AEC report, $1.25, 42 pp., 1951.

RMO-2802 *Recovery of Uranium Values from Ore and Concentrate Samples*, Progress report No. 2, AEC report, $4.50, 167 pp., 1955.

RMO-2804 *Recovery of Uranium Values from Ore and Concentrate Samples, Pilot Plant Test Operations*, Progress report No. 4, AEC, $1.25, 39 pp., 1955.

WIN-31 *A Solvent Leaching Process for the Production of High-Purity Uranium Products Directly from Low-Grade Ores, AEC report*, 75¢, 22 pp., 1955.

WIN-54 *Laboratory Investigation of Dakota Lignites*, AEC report, $4.50, 167 pp., 1957.

HW-49652A *Continuous Calcination Equipment for Converting UNH to UO_3*, AEC report, 50¢, 17 pp., 1957.

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AEC-tr-2855 *The Statistical Theory of Phase Transitions*, by B. T. Geilikman, 45¢, 77 pp., 1954.

AEC-tr-2876 *Quantum Electrodynamics, Parts 1 and 2*, by A. I. Akhiezer and V. B. Berestetsky, $2.65, 549 pp. (in 2 vols.), 1953.

AEC-tr-2873 *Theoretical Principles of Isotope Methods for Investigating Chemical Reactions*, by S. Z. Roginsky, Inst. of Physical Chemistry, Academy of Sciences, USSR, $2.20, 456 pp., 1956.

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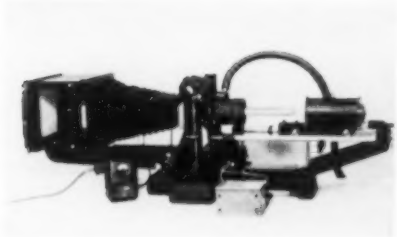

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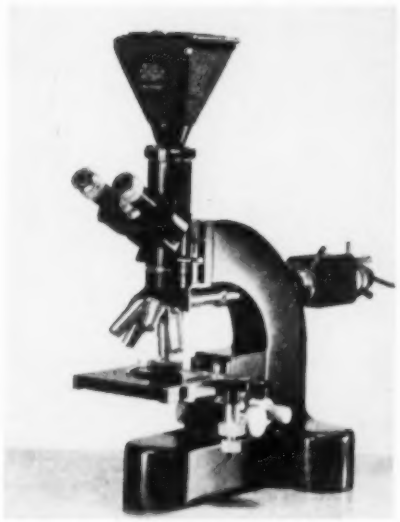

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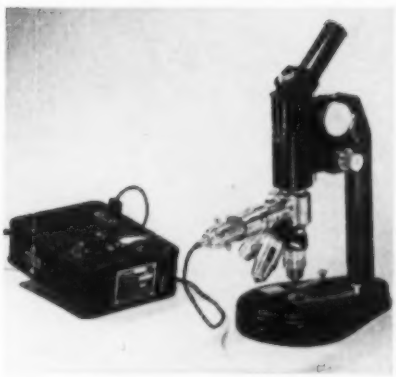

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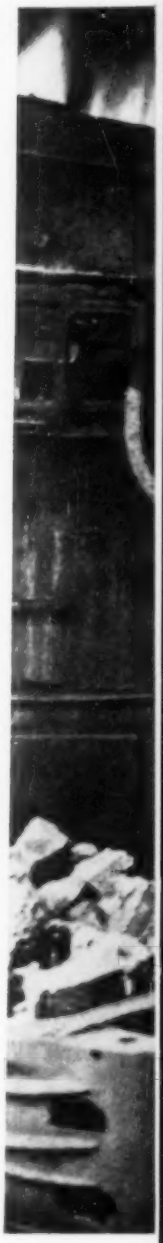

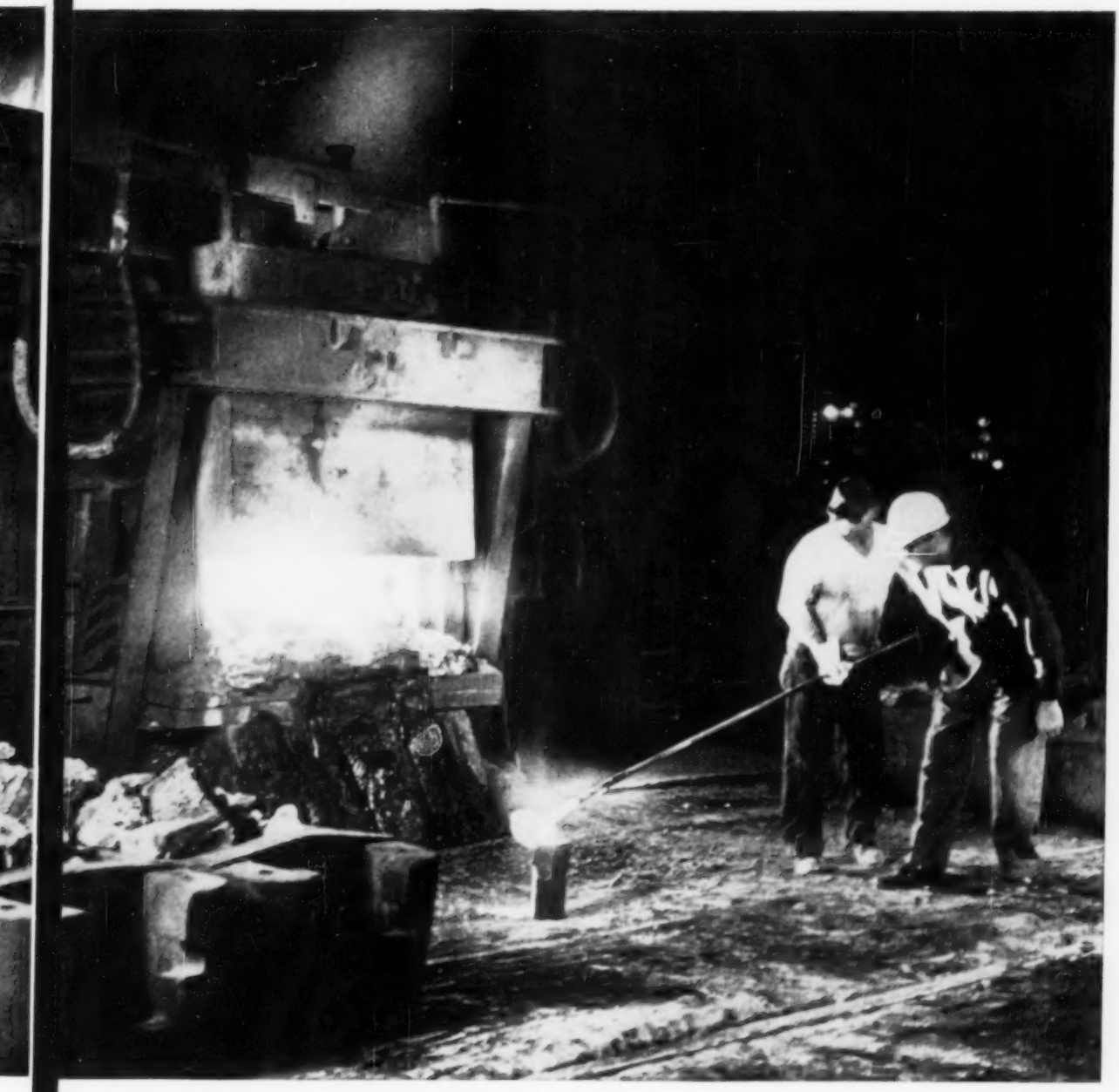

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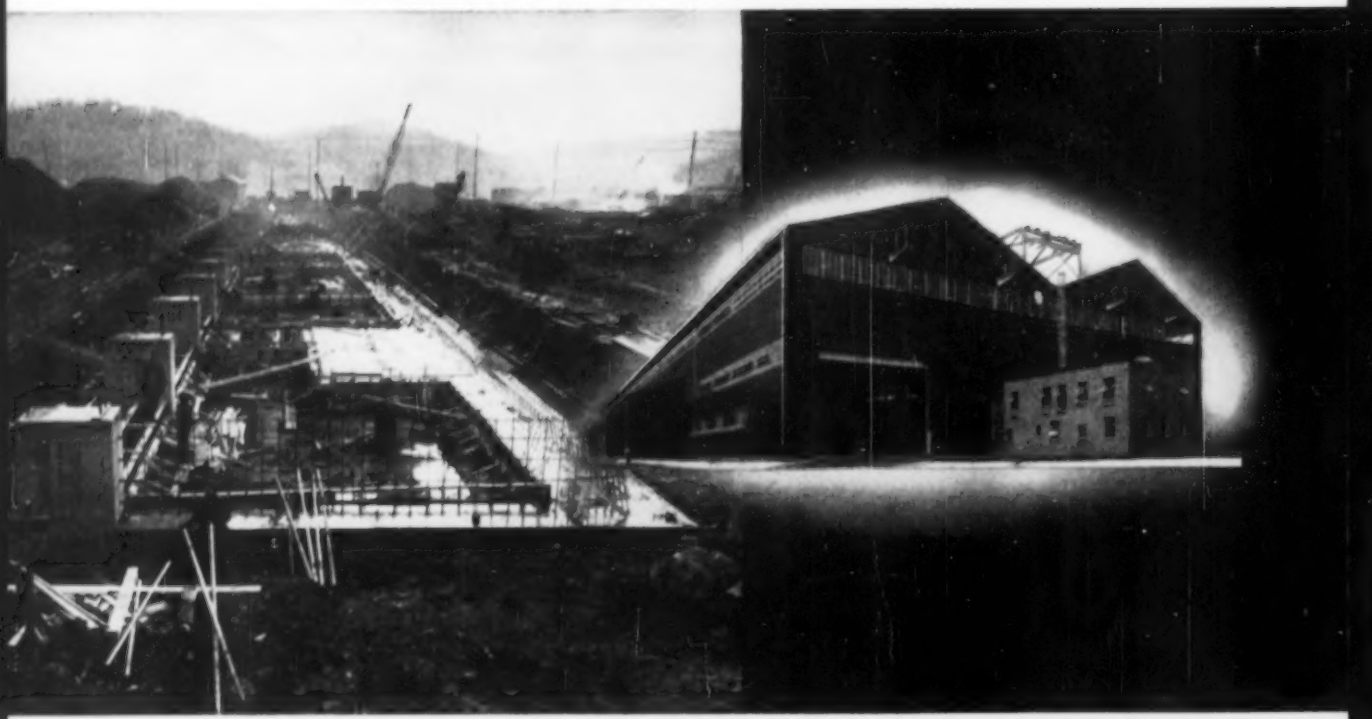

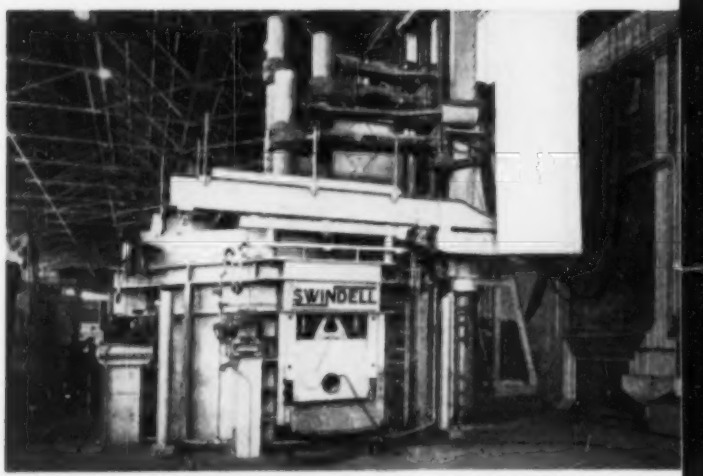

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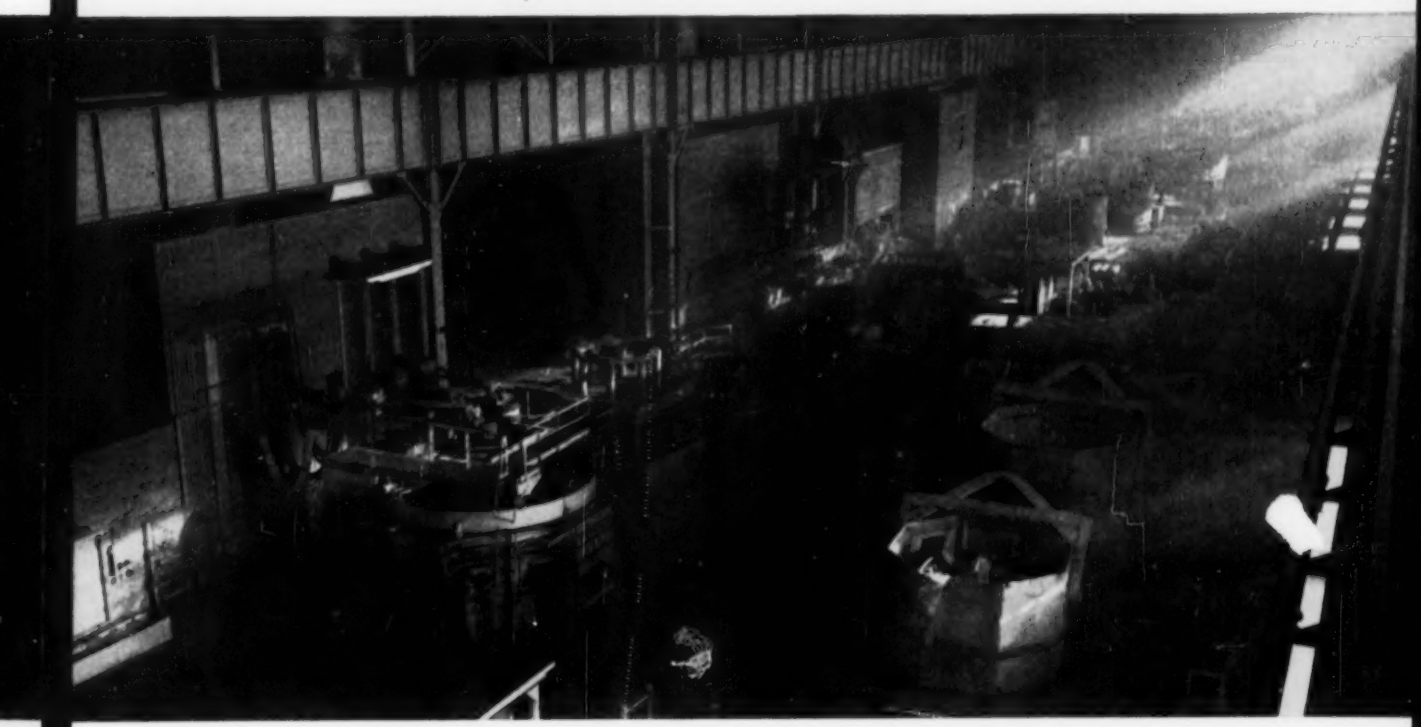

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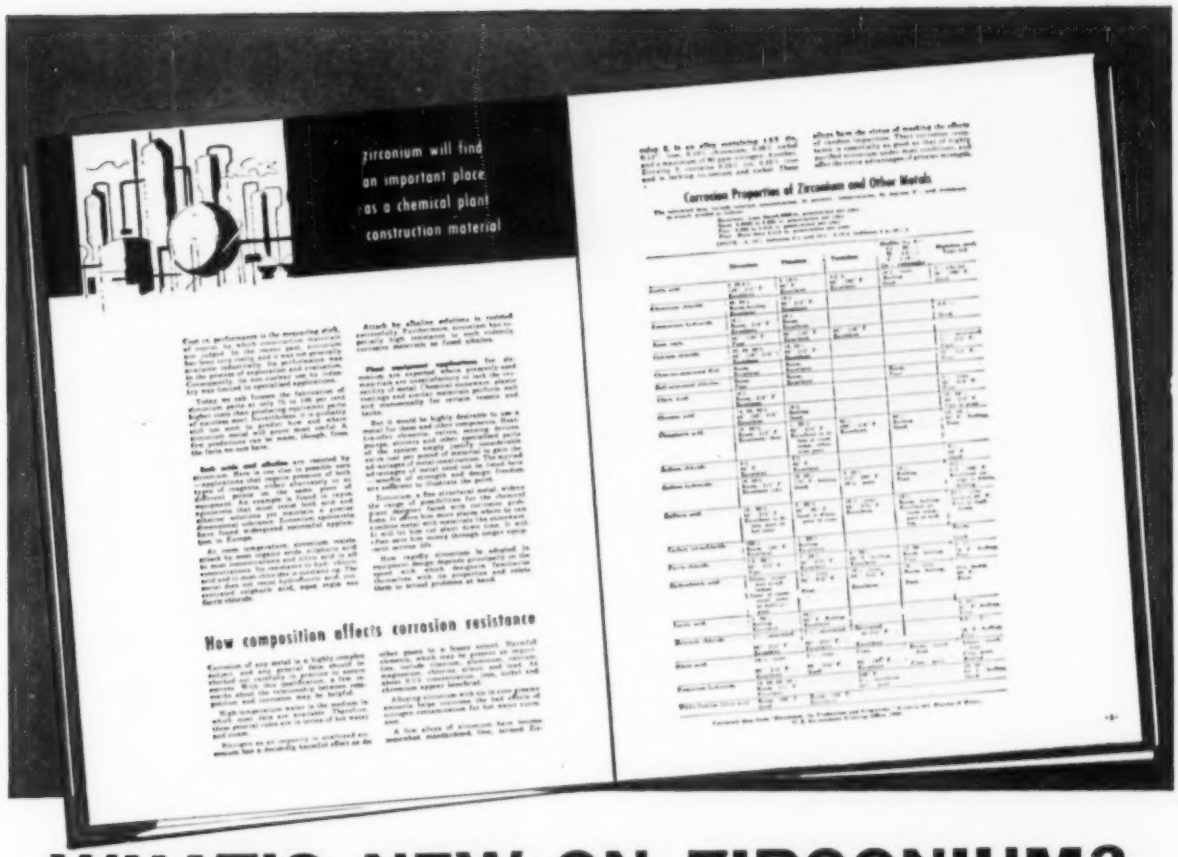
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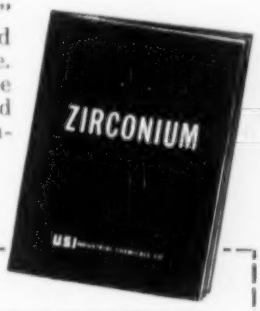

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News of EDUCATION

► The International Nickel Co. Inc. has established a Chair in Chemical Metallurgy at Columbia University. Formal acceptance of the Chair, which is endowed by a grant of $350,000, was disclosed as a result of action taken in the first fall meeting of the University trustees in October. In addition to the basic grant, the company made a gift of $75,000 for special expenditures incidental to establishment of the Chair.

The new Chair has been designated as the Stanley-Thompson Chair of Chemical Metallurgy in honor of two alumni of Columbia's School of Mines—Robert Crooks Stanley, chairman of the board and chief officer of Inco until his death in 1951, and John Fairfield Thompson, chairman of the board and chief officer of Inco since 1951.

Jack Henry Schulman of Cambridge University, England, has been appointed first incumbent of the Chair. He began his Columbia teaching duties immediately following the appointment. Dr. Schulman has been reader in surface chemistry and a fellow of Trinity Hall, Cambridge. He recently resigned his position as director of the Ernest Oppenheimer Laboratory in the Dept. of Colloid Science at the English University.

In making the grant, Henry S. Wingate, president of Inco, explained that the company wished to support fundamental research in the surface chemical and physical aspects of many problems in mineral beneficiation and extraction metallurgy.

► Morse Brothers Machinery Co., Denver, has made a second contribution of $1000 to the Colorado School of Mines. The gift is the second payment on a $5000 pledge made by the company last year. This particular portion of the pledge payment has been restricted to the capitol improvement program being directed by the Colorado School of Mines Foundation Inc.

► The world's first Junior Solar Symposium will be held on Mar. 1, 1958, at Arizona State College, Tempe, Ariz., and is under the sponsorship of the Assn. for Applied Solar Energy, the College, and the Arizona Junior Academy of Science. The Symposium will provide an opportunity for students below the college level to take part in a scientific meeting.

Part of the Symposium will be a contest for entries of an exhibit accompanied by a paper describing the research study upon which the exhibit is based. All entries are to be based on some phase of solar energy and must be submitted no later than Feb. 12, 1958, in order to be judged. Prizes will be awarded for the best entries and those winners will be invited to present their papers at the Symposium. Application blanks for entry may be obtained from the Assn. for Applied Solar Energy, 3424 North Central Ave., Phoenix, Ariz.

► Candidates for engineering positions with the Federal Government are invited by the U. S. Civil Service Commission to file for positions. The announcement No. 112B was issued July 30, 1957, and there is no closing date. Candidates must hold a B. S. degree from an accredited college or university with a suitable curriculum in engineering or closely related fields or have the equivalent technical engineering experience or combination of experience and education. In addition, certain levels of engineering positions have certain professional engineering experience requirements. Candidates must be U. S. citizens or owe allegiance to the U. S. and must be able physically to perform the duties of a given position. Students who will complete their senior year or graduate course nine months dating from July 30 are eligible to apply. Further information and announcement No. 112B may be obtained from the Executive Secretary, Board of U. S. Civil Service Examiners, Washington 25, D. C.

► Senior postdoctoral fellowships will be awarded on Mar. 18, 1958, by the National Science Foundation. Approximately 25 senior postdoctoral fellowships will be awarded to persons planning additional study and/or research to 1) increase their competence in their specialized fields of science or 2) broaden their competence in related fields of science. For full information in regard to eligibility for and provisions of these fellowships write to: Div. of Scientific Personnel and Education, National Science Foundation, Washington 25, D. C. Application materials may also be obtained from this division and completed materials must be received by the division no later than Jan. 13, 1958.

► Oct. 31, Nov. 1 to 2, Edgewater Beach Hotel, Chicago. Sponsored by Engineering Manpower Commission of EJC; Scientific Manpower Commission; National Science Foundation; National Research Council; local sponsors: Western Society of Engineers. Purpose was to update facts on "Engineering and Scientific Education—Foundation of National Strength". Participants included Lee A. DuBridge, president of California Institute of Technology; M. H. Trytten, National Academy of Science; Gordon B. Carson, Dean of Engineering, Ohio State University; J. S. Nicholas, Department of Zoology, Yale; W. C. Fels, president of Bennington College; W. H. Miernyk, Northwestern University; and others.

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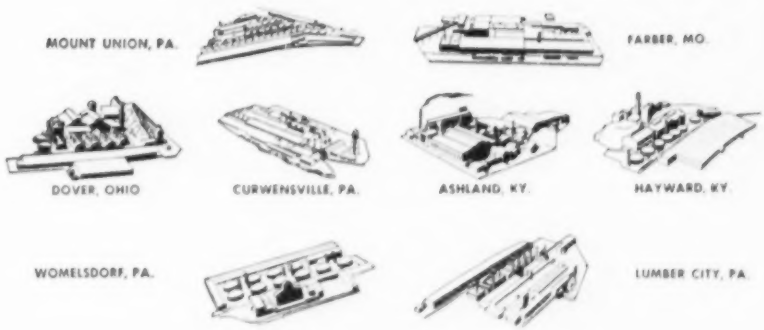

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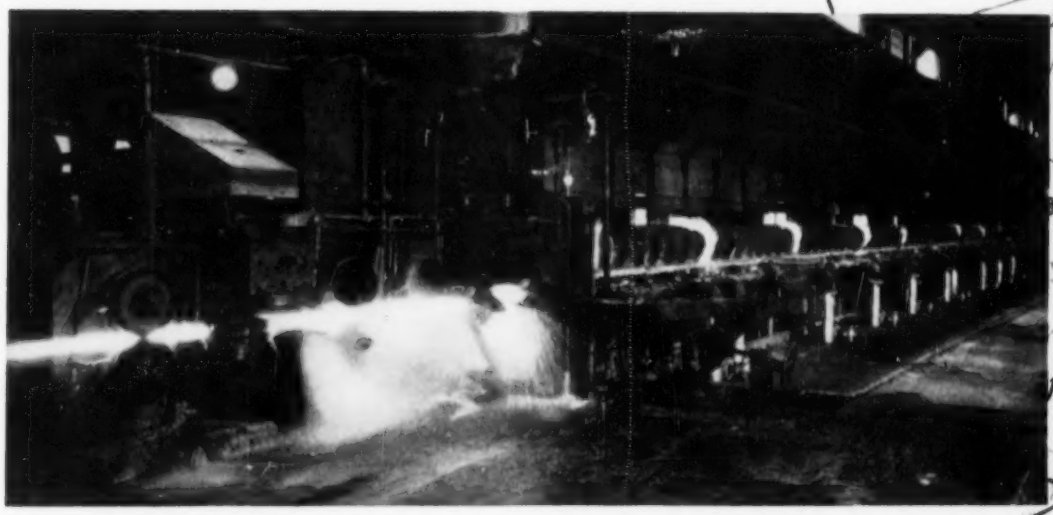

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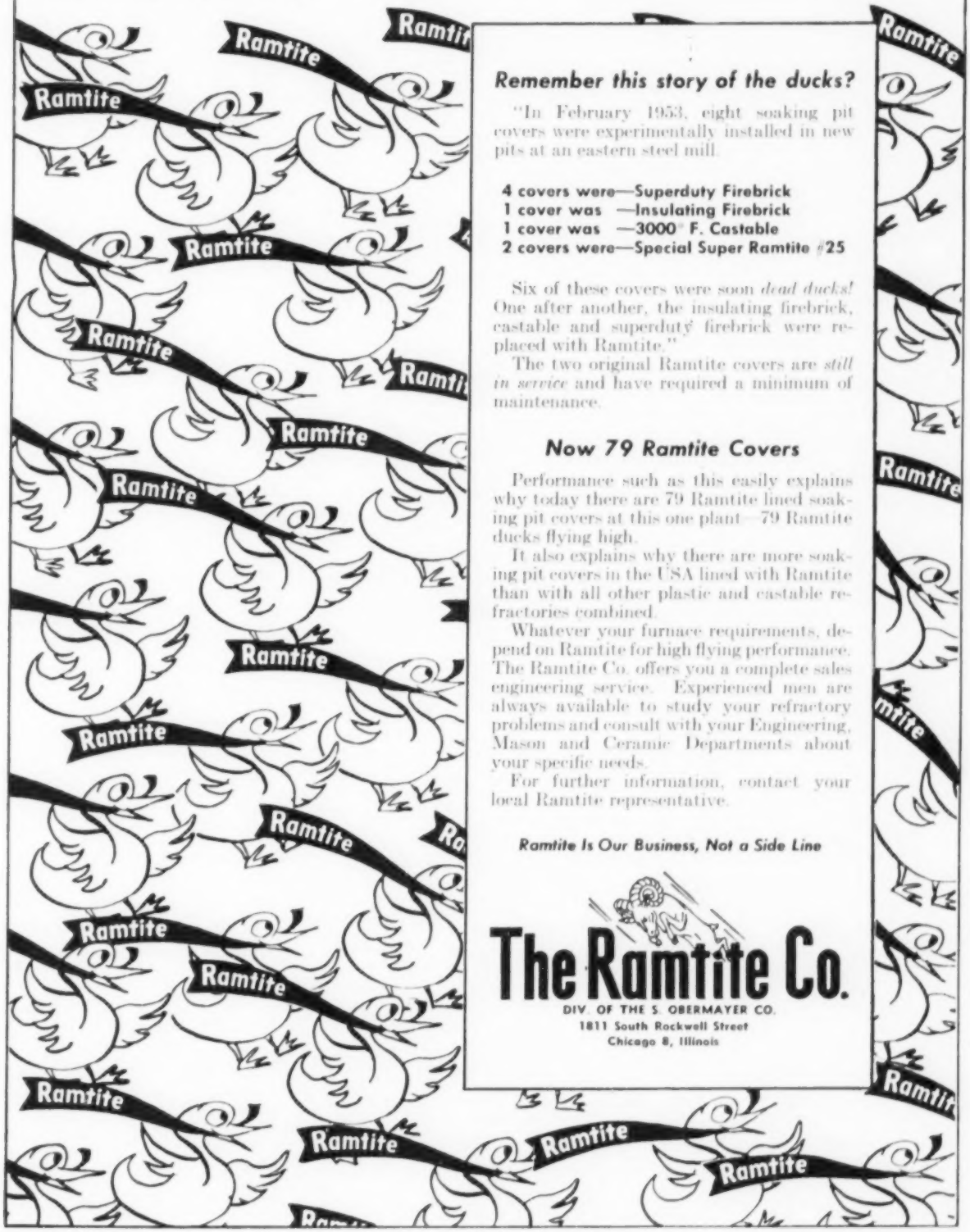

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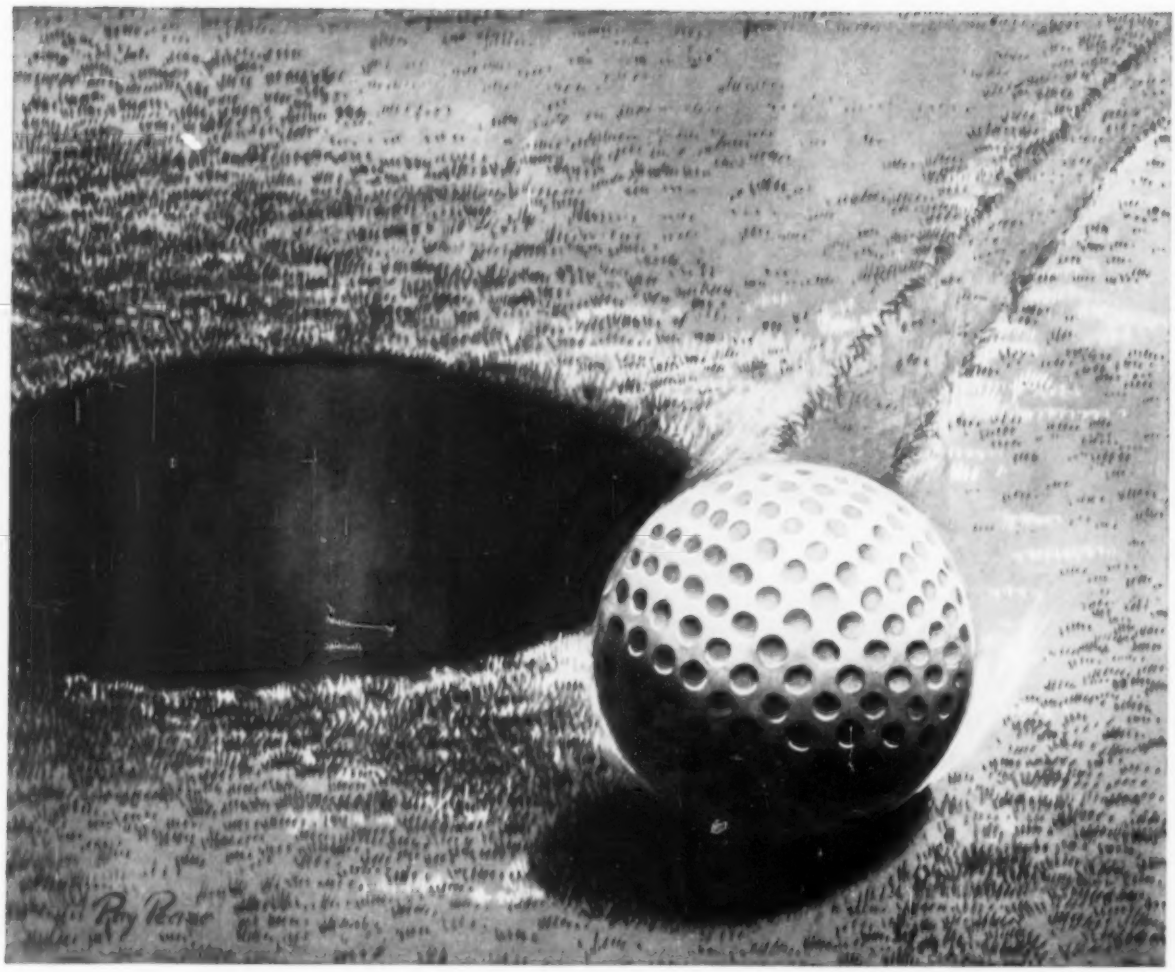

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1943	414	1948	534	1953	749
1944	569	1949	585	1954	882
1945	500	1950	620	1955	949
1946	546	1951	752	1956	979
1947	569	1952	823	1957	?

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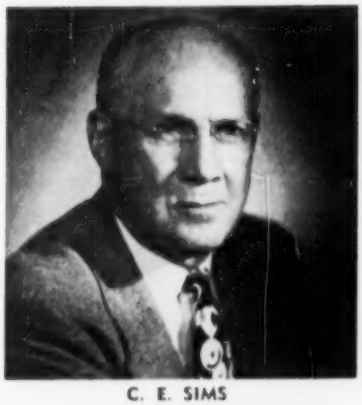
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Program

Electric Furnace Steel Conference

REGISTRATION

Wednesday, December 4-9:00 am to 9:00 pm—Fort Duquesne Room
Thursday and Friday, December 5 and 6—8:30 am to 5:00 pm—Fort Duquesne Room

WEDNESDAY, DECEMBER 4

Plant Trip:

Babcock and Wilcox Co., Beaver Falls, Pa.

Chartered buses will leave from the Grant St. entrance of the Penn-Sheraton Hotel at 10:00 am. Lunch will be provided by the host company. Buses will return to the Penn-Sheraton Hotel by 5:00 pm.

WEDNESDAY, DECEMBER 4

6:30 pm—Suites 468-470

Electric Furnace Steel Committees Annual Dinner and Business Meeting
(All Chairmen of technical sessions are invited to attend)

THURSDAY, DECEMBER 5

General Session

9:30 to 9:45 am—Ball Room

Welcoming Remarks:

By V. E. Zang, Chairman, Committee for the Fifteenth Annual Conference.

Response:

By D. L. Clark, Chairman, Electric Furnace Steel Committee—Announcements and Reports

Nitrogen in Electric Furnace Steel

(Organized by Physical Chemistry of Steelmaking Committee)

9:45 am to 12:30 pm—Ball Room

Chairmen:

A. F. Gross, Research Metallurgist, The Ohio Steel Foundry, Springfield, Ohio

Gerhard Derge, Jones and Laughlin Professor of Metallurgy, Carnegie Institute of Technology, Pittsburgh, Pa.

1. **Application of Nitrogen Solubility Data to Alloy Steelmaking**
   Paper by Fredrick C. Langenberg and Maurice J. Day, Crucible Steel Company of America, Research and Development Laboratory, Pittsburgh, Pa.

ANNUAL DINNER

Thursday, December 5

6:30 pm—Urban Room, Reception and Cocktail Party for dinner guests
7:00 pm—Ball Room, Dinner

Toastmaster: Stanley M. Norwood, Assistant to President, and Vice-President, Electro Metallurgical Co., Division of Union Carbide Corp., New York, N. Y.

Speaker: Edward A. Livingstone, Vice-President, The Babcock and Wilcox Co., Head of the Tubular Products Division, Beaver Falls, Pa.

Subject: *The Atomic Age Challenge to Steel*

a) Lead-off Discussion: D. J. Girardi, Metallurgical Engineer, Timken Roller Bearing Co., Canton, Ohio.

2. **Nitrogen—Porosity Relations in Chromium-Nickel-Manganese Steels**
   Paper by G. R. Adams, J. Thompson, and W. O. Binder, Product and Process Development Department, Electro Metallurgical Co., Division of Union Carbide Corp., Niagara Falls, N. Y.

3. **Sampling and Analysis of Nitrogen in Electric Furnace Steels—Review and Evaluation of Modern Methods**

   a) Aqueous Solution Methods
   Paper by R. H. Colin, Chief Chemist, Duquesne Works, United States Steel Corp., Duquesne, Pa.

   b) Vacuum Fusion Methods
   Paper by W. A. Peifer, Research Advisor, Research Laboratories, Allegheny Ludlum Steel Corp., Brackenridge, Pa.

   c) Comparison of Methods on Duplicate Furnace Samples
   Paper by A. F. Gross, Research Metallurgist, The Ohio Steel Foundry, Springfield, Ohio

   d) Analysis of Steel for Nitrogen and Its Compounds
   Paper by H. F. Beeghly, Research Associate, Jones and Laughlin Steel Corp., Pittsburgh, Pa.

Physical Chemistry of Steelmaking Committee Luncheon and Business Meeting

12:30 p.m—Grant Room

Refractories

2:00 to 5:00 pm—Ball Room

Chairmen:

A. J. Scheid, Jr., Vice-President in Charge of Manufacturing, Columbia Tool Steel Co., Chicago Heights, Ill.

P. R. Gouwens, Chief Metallurgist, Fahralloy Co., Harvey, Ill.

1. **Cast and Rammed Sections in Arc Furnace Roofs**
   Preprinted paper by J. D. McCullough, Chief Engineer, Refractories Division, Babcock and Wilcox Co., New York, N. Y.

2. **Canadian Basic Refractory Practice in Electric Furnaces**
   Preprinted paper by A. H. Thomson, District Sales Manager, Canadian Refractories Ltd., Montreal, Quebec.

3. **Tar-Bonded Basic Refractories**
   Paper by J. P. Holt, Executive Assistant to Vice President-Sales, Basic, Inc., Cleveland, Ohio.

4. **Furnace Bottoms—Installation of Thermocouples in Electric Furnace Hearths**
   Paper by T. J. Wayne, Superintendent, No. 2 Electric Furnace Department, South Works, United States Steel Corp., Chicago, Ill.
   Discussion by L. E. Holmes, Foreman, Instrument Mechanics, Timken Roller Bearing Co., Canton, Ohio

5. **Ladle Refractories—Self-Baking Refractory Mix**
Paper by L. A. Stoyell, Product and Process Development Department, Electro Metallurgical Co., Division of Union Carbide Corp., Niagara Falls, N. Y., and T. R. Culbert, Case Institute of Technology, Cleveland, Ohio

FRIDAY, DECEMBER 6

Vacuum Melting: Electric Arc Furnace Practice Variables on Quality

9:30 am to 12:30 pm—Ball Room

Chairmen:

H. O. Beaver, Jr., Plant Metallurgist-Melting, The Carpenter Steel Co., Reading, Pa.

J. Nisbet, President, Allvac Metals Co., Monroe, N. C.

Part I—Vacuum Melting

1. **Overall Summary of Vacuum Melting**
Paper by C. T. Evans, Jr., Vice-President, Technology and Development, Universal Cyclops Steel Corp., Bridgeville, Pa.

2. **Consumable Electrode Vacuum Melting**
Paper by Helmut Gruber, Director of Vacuum Plant and Vacuum Metallurgical Department, W. C. Heraeus, GMBH, Hanau, Germany

3. **Induction Vacuum Melting**
Paper by F. M. Darmara, General Manager, Metals Division, Utica Drop Forge and Tool Co., Utica, N. Y.

Part II—Panel Discussion on Furnace Practice Variables and Their Effect on Quality of Aircraft and Bearing Steels

1. **Aircraft Steels**
Paper by P. Adams, Process Metallurgist, and L. Barnhardt, Melting Superintendent, Atlas Steels Ltd., Welland, Ontario

2. **Recarburizing Bearing Steels**
Paper by William Spicer, Chief Process Metallurgist, United States Steel Corp., Duquesne, Pa.

3. **52100 Bearing Steels**
Paper by A. K. Blough, Superintendent No. 2 and No. 3 Melt Shop, Republic Steel Corp., Canton, Ohio

Foundry Practices

9:30 am to 12:30 pm—Urban Room

Chairmen:

J. W. Tibbits, Assistant Works Manager, Canadian Steel Foundries (1956) Ltd., Montreal, Quebec

N. H. Keyser, Assistant Chief, Process Metallurgy, Battelle Memorial Institute, Columbus, Ohio

1. **Oxygen as an Aid in Electric Furnace Melting**
Paper by G. Tracey, Melting Superintendent, Canadian Steel Foundries (1956) Ltd., Montreal, Quebec
Paper by V. E. Belusko, Casting Metallurgist, and L. E. Fink, Metallurgist, Electric Steel Foundry, Portland, Ore.

2. **Some Aspects of Melting Low-Temperature, High-Impact Steels**
Preprinted paper by W. A. Koppi, Melting Superintendent, Lebanon Steel Foundry, Lebanon, Pa.

3. **Spectrographic Analysis in Foundry**
a) Fluorescent X-Ray Spectrographic Analysis
Paper by Earl Anger, Chief Metallurgist, Duraloy Co., Scottsdale, Pa.
b) Standardization and Use of the Spectromet in a Steel Foundry
Preprinted paper by C. L. Richards, Vice-President-Metallurgy and Research, Adirondack Foundries and Steel Inc., Watervliet, N. Y., and Henry Levesque, Sales Manager, Baird Atomic, Inc., Cambridge, Mass.
c) The Quantovac—A Direct-Reading Instrument for the Control of Carbon, Phosphorus, Sulphur, and the Other Important Elements in Iron and Steel
Preprinted paper by H. W. Calkins, Pittsburgh District Representative, and M. F. Hasler, President, Applied Research Laboratories, Pittsburgh, Pa.

Economic Utilization of Power

2:00 to 5:00 pm—Ball Room

Chairmen:

G. G. Zipf, Steel Plant Superintendent, Babcock and Wilcox Co., Beaver Falls, Pa.

C. W. Vokac, Manager, Hydro-Arc Division, Whiting Corp., Harvey, Ill.

1. **Power Utilization and Control in the Electric Furnace Steel Plant**
Paper by F. W. Foster, Senior Industrial Power Engineer, West Penn Power Co., Greensburg, Pa.
Discussion by H. V. Miller, Assistant to the Superintendent of Power, Armco Steel Corp., Middletown, Ohio
Discussion by E. H. Browning, Manager, Metal Working Section, Industry Engineering Dept., Apparatus Division, Westinghouse Electric Corp., Pittsburgh, Pa.

2. **An Effective Demand Limiting System for the Electric Furnace Melt Shop**
Paper by C. A. Scammon, Chief Electric Engineer, Allegheny Ludlum Steel Corp., Brackenridge, Pa.
Discussion by Harold Booth, Copperweld Steel Corp., Warren, Ohio

3. **Improvements in Arc Furnace Power Regulation and Electrode Hoisting Systems**
Paper by Frank Nicholson, Engineer, Swindell-Dressler Corp., Aspinwall, Pa.

4. **Analysis and Practical Results Obtained From a Study of Arc Furnace Control**
Preprinted paper by J. H. Kogen, Chief Development Engineer, Askania Regulator Co., Chicago, Ill.
Discussion by R. J. McCurdy, Melt Shop Superintendent, Republic Steel Corp., South Chicago, Ill.
Discussion by J. R. Lee, Director-Engineering Design, Vanadium Corp. of America, Cambridge, Ohio
Discussion by F. D. Shaw, Research Electrical Engineer, American Smelting and Refining Co., South Plainfield, N. J.

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1956 BLAST FURNACE PROCEEDINGS VOL. 15

The Proceedings of the 1956 Conference of the Blast Furnace, Coke Oven, and Raw Materials Committee, Iron and Steel Division, AIME, can be purchased by those unable to attend the Conference held in Cincinnati, April 9-11, 1956.

Use the convenient order form below.

Several volumes of recent Conferences are still in stock, and can also be purchased.

These valuable papers were presented at the 1956 Conference:

Sizing and Sintering of Ores

Design and Operation of No. 3 Sinter Strand at Jones and Laughlin's Benson Mines. By R. G. Fleck and F. M. Hamilton.

The Lurgi Sintering Plant of the Steel Company of Canada. By T. W. W. Trumper.

Ore Preparation Plant of The Steel Company of Wales Limited—Design, Operation, and Effect on Blast Furnace Performance. By K. C. Sharp and H. R. Tufnail.

Weirton's New Eight-Foot Wide Iron-Ore Sintering Plant. By Julius H. Strassburger.

Blast Furnace Operations

Operating Experiences with High Beneficiated Burdens. By D. Joyce, W. P. Dowhaniuk, and B. Marsden.

The New High-Grade Iron Ores and Agglomerates and Their Effect on Coke Rates. By John Griffen.

Burdening a Blast Furnace for Minimum Costs. By David R. Bailey.

Comparison of Blast Furnace Penetration with Model Studies. By J. B. Wagstaff and W. H. Holman.

Desulphurization of Hot Metal

Application of Theoretical Principles to Desulphurization in Iron and Steel Making. By John F. Elliott.

Desulphurization with Calcium Cyanamid in Hot-Metal Ladles. By G. G. Hatch, G. E. Wagner, and M. Trottier.

Desulphurization of Molten Iron. By J. N. Hornak and E. J. Whittenberger.

Desulphurization of Blast Furnace Iron with Injected Calcium Carbide. By Daniel E. Watkins and J. R. McFarland.

Coal and Coke

Pilot-Scale Coke Ovens—Development and Operation. By R. Tracy Eddinger and John Mitchell.

New Pressure-Recording 18-Inch Test Oven. By R. P. Aikman.

Study of Pressure Relationships in Commercial Coke Ovens. By D. C. Coleman and P. J. Farley.

Low Fuel Rates Obtained with Three-Foot Blast Furnace Using Prepared Ores and Coke-Anthracite Mixtures. By Russell C. Buehl and Miles B. Royer.

Research and Development on Sintering

Reaction Zones in the Iron-Ore Sintering Process (JOURNAL OF METALS Award Paper). By R. D. Burlingame, Gust Bitsianes, and T. L. Joseph.

Sintering Investigations Using Factorial Design Experiments. By T. L. Myron, C. J. Davis, and R. L. Franklin.

Methods for Increasing Production Rate of Flue-Dust Sinter. By E. C. Rudolphy and E. J. Whittenberger.

Sintering Iron Ores and Concentrates at Estaca. By Robert L. Bennett, Robert E. Hagen, and Morris V. Mielke.

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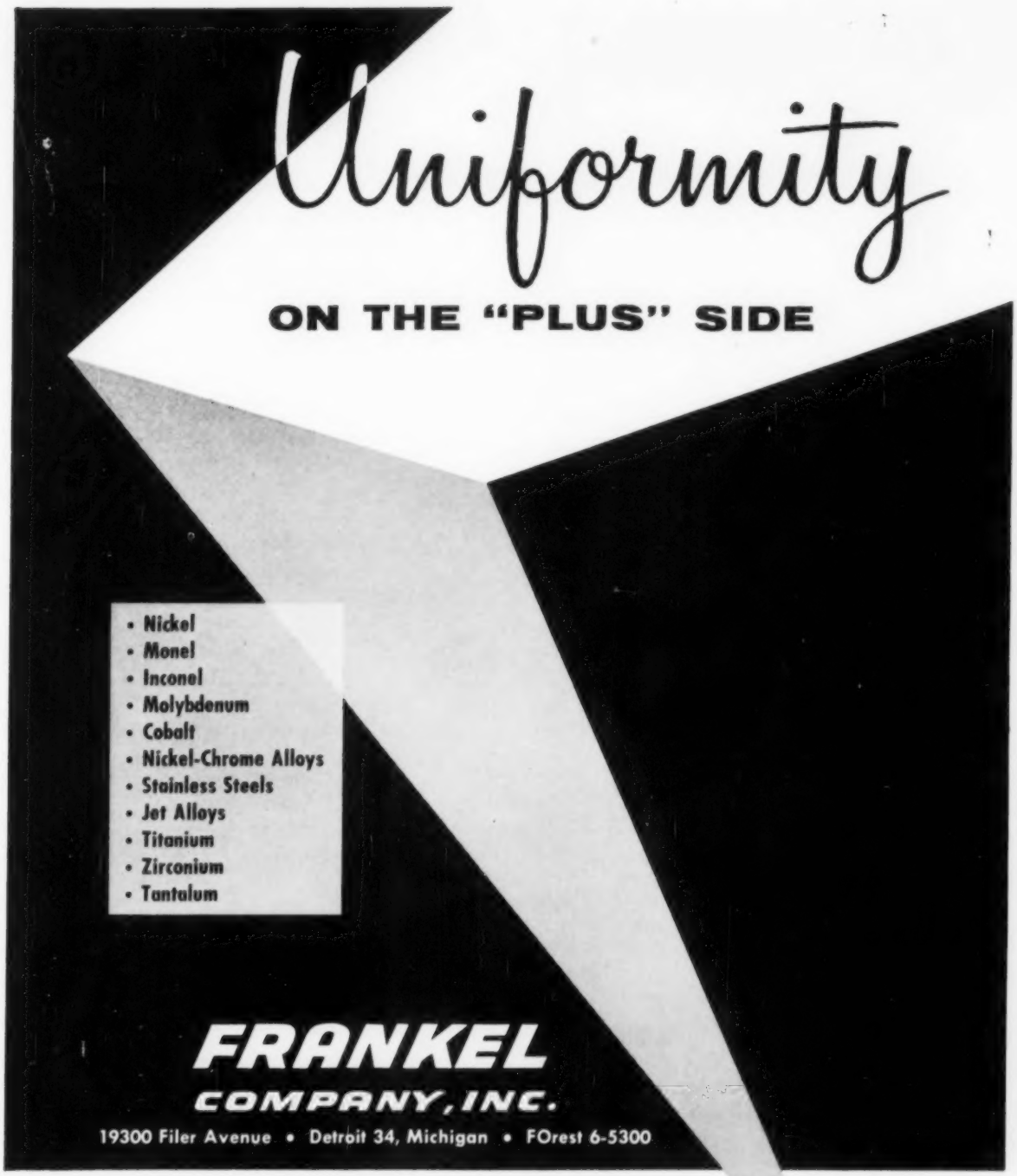

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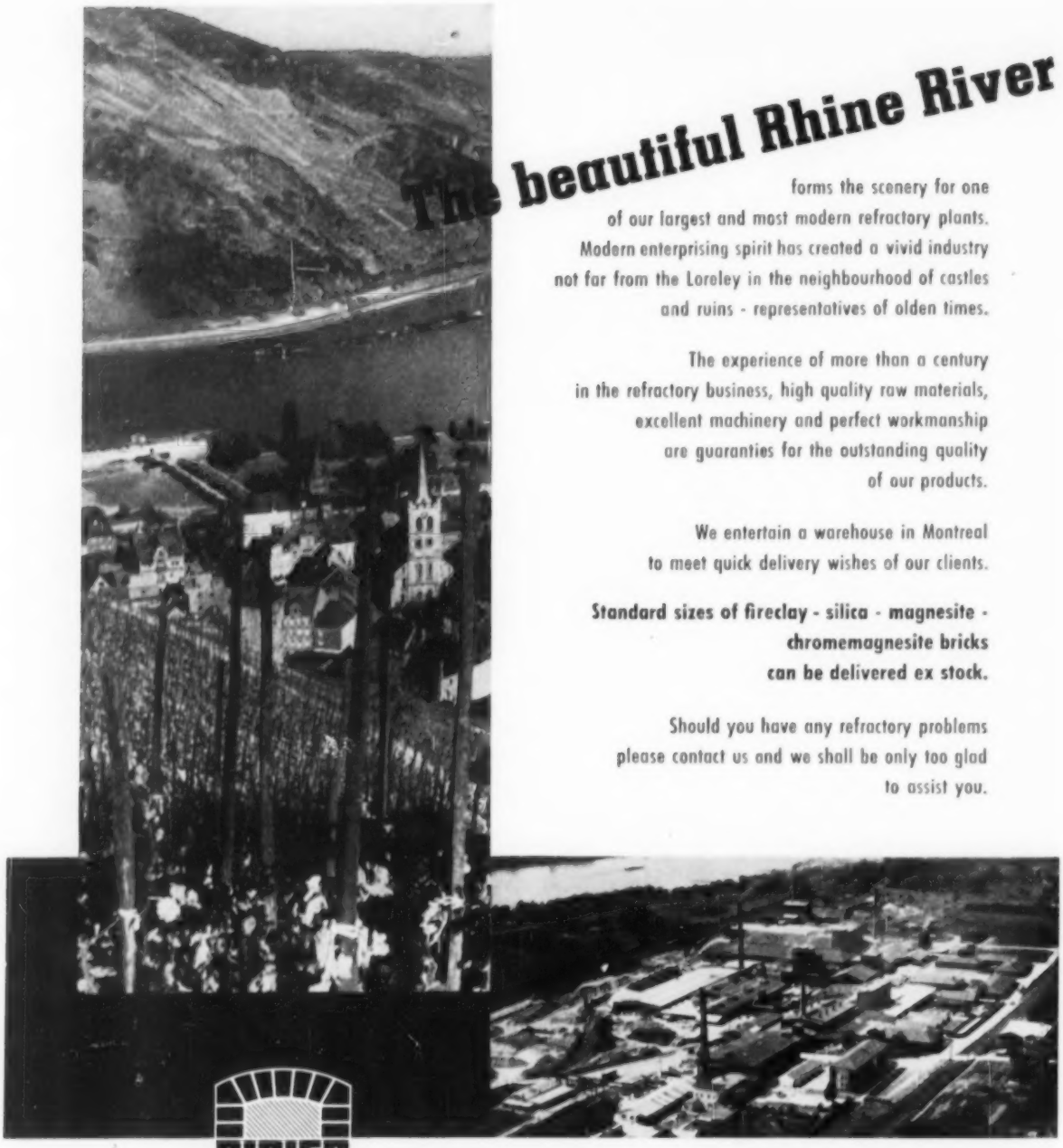

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EDITORIAL

UET

Plans for United Engineering Center

THE new United Engineering Center will be erected on United Nations Plaza between 47th and 48th Sts. in New York City, as shown in the sketch of location below.

Designed to symbolize the dignity and achievements of the engineering profession, the Center will provide national headquarters for the continued advancement of engineering and technology. Not only will adequate facilities be provided for performing present functions, but sufficient provision will be made to include continuing growth of services to the engineering profession.

A 20-story tower surrounded by lower structures with landscaped surroundings, the new Center will offer almost three times the usuable space in the present Engineering Societies' Building. In addition to space requirements of the Societies, rooms for engineering meetings and committe activity will be provided. Private dining rooms for engineers attending meetings are planned, as is a cafeteria.

Enlarged library and publication facilities are included in plans for the new Center. An exhibition space is planned in which the rapid advances in engineering will be interpreted for the general public. And, in keeping with the traditions and dignity of a proud profession, a memorial hall is planned to perpetuate the contributions of great engineers to the effectiveness of American civilization.

The Center will permit expansion for all foreseeable needs for the next half-century, will be attractive without being ornate, and will embody dignity without implying pretension.

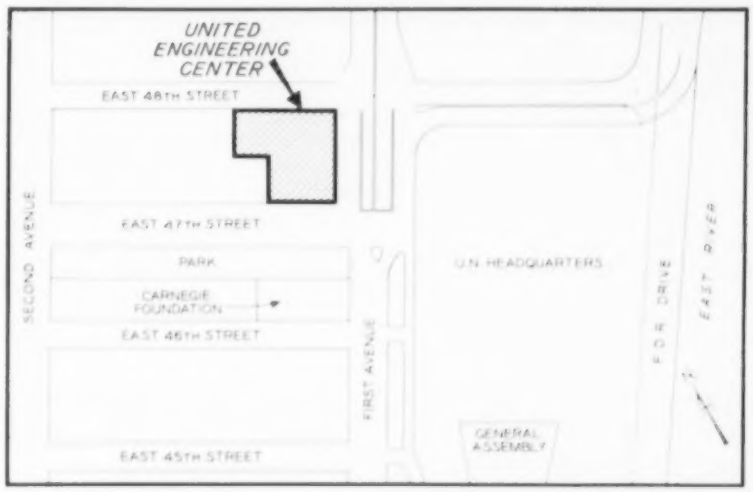
The new Center will represent the culmination of plans on the part of United Engineering Trustees Inc. and the Five Founder Societies, that date back to the fall of 1955 when a task committee of 15—three from each Society—was appointed. This committee had its first meeting on Oct. 10, 1955, and on June 22, 1956, submitted the following report:

- Item 1—The Engineering Societies' Center be located in New York City.
- Item 2—The 39th-40th Street site be continued in use as the site of the Engineering Societies' Center.

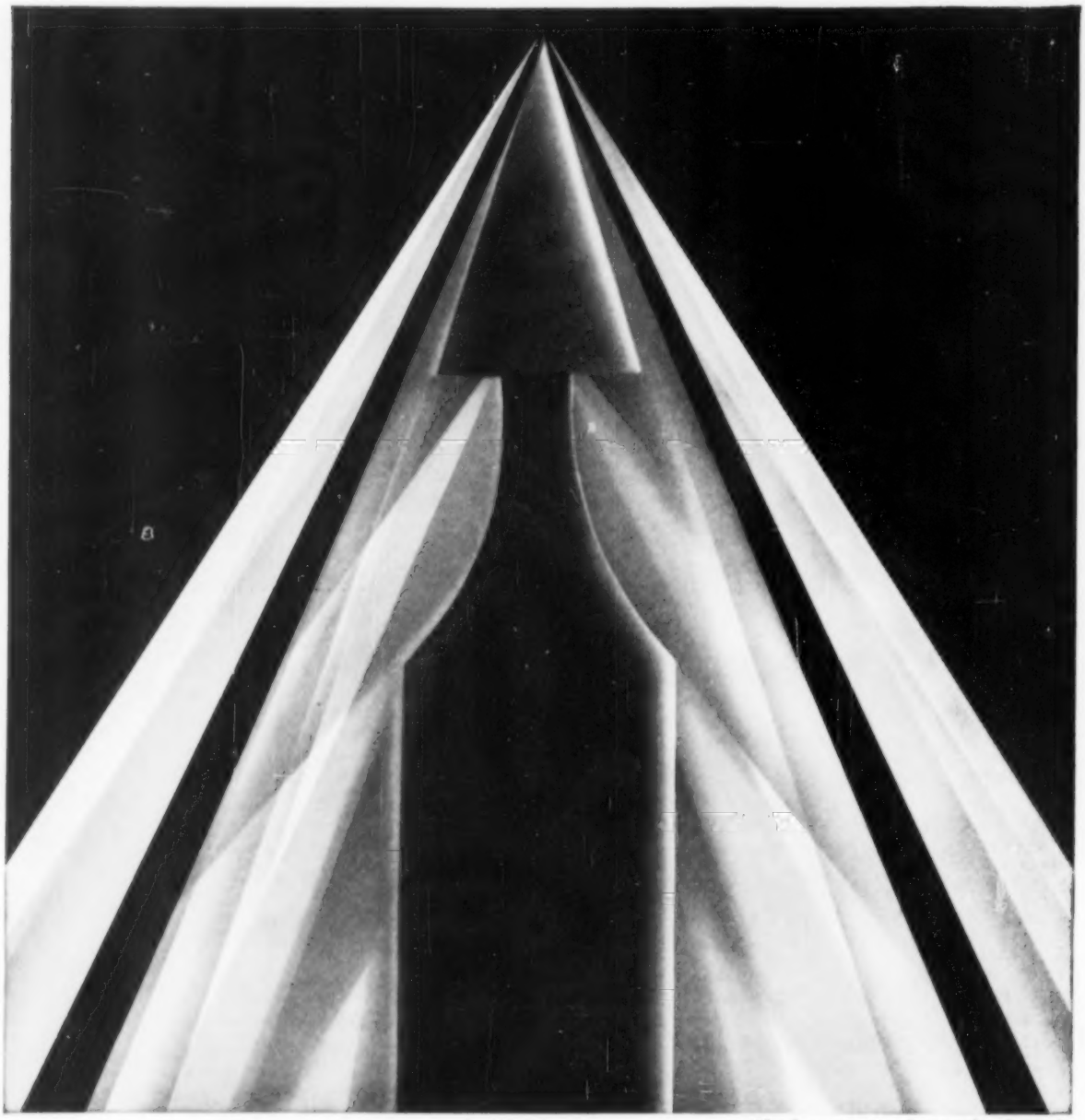
  "If rebuilding in that area proves impracticable, a comparable site should then be sought in midtown New York."

Approval of the recommendations was completed by the end of November 1956 and the firm of Shreve, Lamb & Harmon Assoc. was retained to assist in determining the feasibility of developing the present building site. After thorough study, the Trustees decided on Feb. 12, 1957, to abandon plans for the present site and to seek a new one.

On Aug. 1, 1957, a news story was released announcing the acquisition of a site on United Nations Plaza between 47th and 48th Sts. in New York. The firm of Shreve, Lamb & Harmon Assoc. were retained as architects.



Sketch shows the location of the site of the new United Engineering Center in relation to adjacent crosstown streets, First and Second Aves., and the United Nations headquarters, which lies between First Ave. and the East River in New York. Also visible in the sketch are the park and Carnegie Foundation which lie south of the proposed center.



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by W. W. Dyrkacz

VACUUM MELTING IN THE STEEL INDUSTRY TODAY

Production of vacuum melted steels has grown from the pilot plant category to a major production status within the last few years. The story of this development is told by one of the firms which has done most in this field.

A RECENT survey has shown that, by the end of 1957, facilities will be available in the U. S. for the annual production of about 20 million lb of metal by induction vacuum melting, and about 50 million lb by consumable-electrode, vacuum arc melting. Planned expansion by industry will increase this capacity by the end of 1958 to 27 million lb and 100 million lb, respectively.

Induction vacuum melting

Induction vacuum melting consists of melting in a vacuum chamber using a conventional induction furnace with a zirconia or a magnesia crucible. Melting is done at pressures of approximately 1μ, with either carbon or hydrogen deoxidation used; the metal is cast into conventional molds.

Fig. 1 shows a schematic drawing of such a furnace at the Watervliet Works of Allegheny Ludlum Steel Corp. The main chamber contains two interchangeable furnaces which permit melting of 300 and 2000 lb heats. The raw material charging chamber at the top of the furnace and the mold chamber at the right of the furnace are sealed from the main chamber with valves so that material can be introduced into the furnace and liquid metal withdrawn without breaking the vacuum, thereby permitting semi-continuous operation. The capacity of this furnace is rated at 250,000 lb per month ingot weight. The actual installation now in production at Watervliet is shown in Fig. 2.

Some of the alloys currently being induction vacuum melted are shown in Table I. It is to be noted that induction vacuum melting is particularly applicable to the superalloys which contain large amounts of reactive elements, such as titanium and aluminum, where close control must be maintained.

One of the early metallurgical property improvements brought about by induction vacuum melting was that of creep-rupture strength. With respect to the alloys shown in Table I, this improvement occurred because of closer contol of titanium and aluminum to limits of ± 0.10 pct as compared to limits of ± 0.25 pct in air melting. In addition, the aluminum and titanium in the vacuum melted materials were present in solid solution form rather than in the form of oxides, nitrides, or carbonitrides. In this manner, there was a greater amount of *effective titanium* available for formation of Ni_3TiAl precipitate through which such alloys gain their high temperature strength. It is also theorized that some improvement in strength is gained through elimination by vaporization of such impurity elements as lead, tin, antimony, and bismuth. Improvement in the creep-rupture strength achieved through vacuum melting of high temperature alloys is shown in Fig. 3.

Although induction vacuum melting has been used mostly for superalloys, room-temperature properties of other metals can also be improved. Bearing steels and low-alloy steels have shown an improvement in fatigue strength when produced with a higher degree of cleanliness than is possible by conventional air melting. This is shown in Fig. 4.

Other advantages of induction melting have been improved hot and cold workability, particularly in alloys which are susceptible to stringer-type inclusions.

Consumable-electrode vacuum arc melting

The consumable melting of titanium, zirconium, and molybdenum under vacuum or in inert atmospheres has grown from the research into the production stage during the decade following World War II. The first work on consumable melting of steels under vacuum occurred in the early 1950's, and was prompted by Allegheny Ludlum Steel Corp.'s experience in melting titanium, plus the cognizance of solidification problems associated with certain superalloys. The process, which has come into com-

W. W. DYRKACZ is Manager of Quality Control, Allegheny Ludlum Steel Corp., Watervliet, New York.

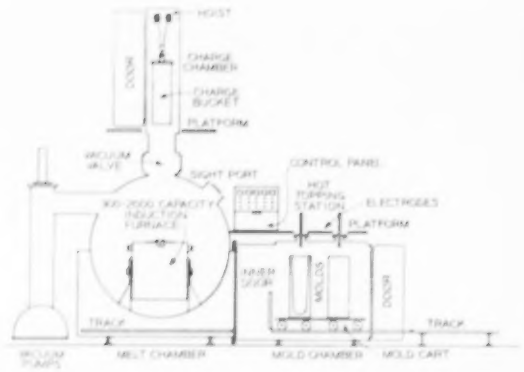

Fig. 1—Vacuum, induction melting furnace units, such as this one, have two interchangeable furnaces which permit melting 300 to 2000 lb heats.

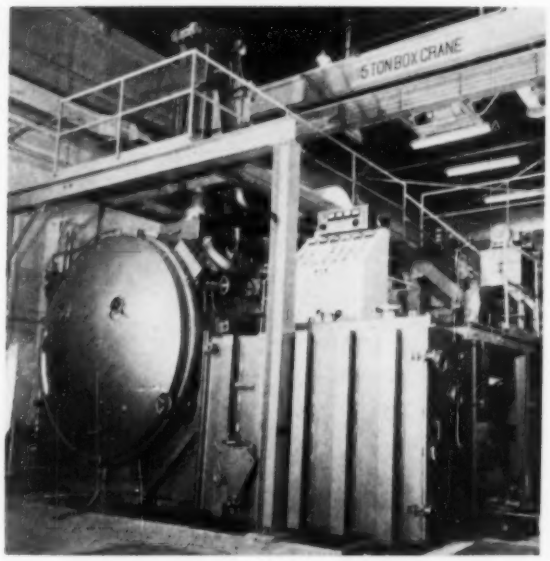

Fig. 2—This vacuum induction furnace at Watervliet Works of Allegheny Ludlum Steel Corp. has a rated capacity of 250,000 lb per month ingot weight.

mercial significance during the last three years, is called consumable-electrode vacuum remelting, and consists of using air-melted electrodes of a predetermined composition and consumably remelting them in a copper, water-cooled crucible at a pressure of 5 to 50μ.

A schematic diagram of the process currently being practiced is shown in Fig. 5. The first installation at the Watervliet Works, which was installed exclusively for melting steel and superalloys in 1955, is shown in Fig. 6. This was followed by additional furnaces in 1956 and 1957 bringing the plant's capacity up to 2 million lb per month, over half of that of the U. S. These facilities permit the melting of ingot sizes from 12-in. diam, 2000 lb, to 26-in. diam, 12,000 lb. Since October 1954, over 20 million lb of superalloys, and stainless, tool and die, bearing, and low-alloy steels have been melted in these facilities.

This expansion in melting facilities has resulted from the increased demand for higher quality materials capable of being produced by this method. Although there has been an improvement in certain metallurgical properties along the lines of those obtained by induction vacuum melting, a major factor in the demand for consumable—electrode melted products stems from two causes: first is the ability to produce larger ingot sizes, both in cross section and weight, and second is a minimization of segregation, especially in alloys containing high-density elements.

Consumable-electrode, vacuum-melted materials show an improvement in fatigue strength in low-alloy steels as well as superalloys. A comparison of the fatigue strength of air-melted and consumable-electrode melted SAE 4340 is shown in Fig. 7. The same heat of material was used for both melting processes and was tested after specimens were heat treated to a tensile strength of 190,000 psi.

An improvement in room-temperature transverse properties of 10½-in. sq billets of SAE 4340 heat-treated to three different tensile strength levels is shown for the air-melted and the consumably-melted metal in Fig. 8.

Since transverse properties are related to segregation, improvement in transverse properties through consumable—electrode vacuum remelting was anticipated because of the fast cooling which *cold-mold* arc melting affords. Microstructural evidence of the decreased segregation is shown in Fig. 9, which compares the microstructure in the center of jet-engine wheel forgings made from large billets of A-286 alloy. The more rapid solidification of consumably-melted ingots results in considerable elimination of the M_3Ti constituent, which not only affects transverse properties deleteriously, but also reduces the response to complete precipitation hardening.

High chemical homogeneity is possible with respect to titanium and molybdenum in consumable-electrode, vacuum remelting. While an 18-in. diam

Table I. Nominal Analyses of Induction, Vacuum Melted, High-Temperature Alloys, Pct.

Element	Waspaloy	M-252	Nimonic 90	Udimet 500	1570	R-235
Carbon	<0.10	0.15	<0.10	0.15	0.20	0.15
Manganese	<1.00	—	<1.0	<0.75	—	—
Sulphur	<0.030	—	—	0.015	—	—
Silicon	<0.75	—	<1.5	0.75	—	—
Chromium	20.0	19.0	20.0	17.5	20.0	15.0
Cobalt	13.5	10.0	18.0	16.5	38.0	—
Molybdenum	3.5	10.0	—	4.0	7.0*	5.5
Titanium	3.0	2.5	2.2	3.0	4.0	2.5
Aluminum	1.25	1.0	1.2	3.0	—	2.0
Iron	<2.0	2.0	<5.0	<4.0	2.0	8.0
Nickel	Bal†	55.0	Bal	Bal	28.0	Bal

* Tungsten.
† Copper less than 0.20 pct.

Table II. Cleanliness Comparison of Conventionally-Melted vs. Consumable-Electrode Vacuum-Melted Low-Alloy, Bearing, and Stainless Steels

Alloy	Melting	ASTM Inclusion Rating, Worst Areas A	B	C	D
SAE 4340	Air-melt electrode	3.0	2.0	0	1.5
	Cons elect vac melt	1.5	0	0	0.5
MHT	Air-melt electrode	1.75	1.5	0	1.75
	Cons elect vac melt	0.5	1.0	0	1.5
403 Stainless	Air-melt electrode	1.0	1.5	0	1.5
	Cons elect vac melt	0.5	0.5	0	0.5
404A Stainless	Air-melt electrode	1.0	1.0	2.5	1.5
	Cons elect vac melt	0	0	0	0.5

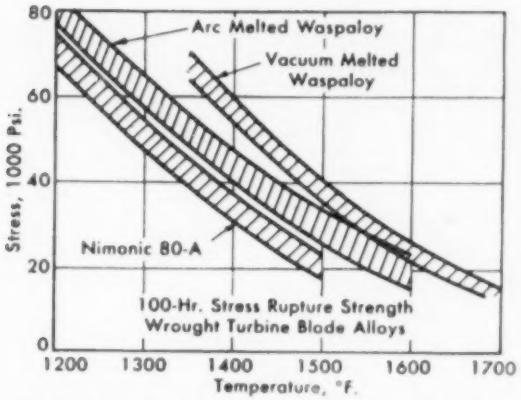

Fig. 3—Scatter bands of stress-rupture tests on two wrought turbine-blade alloys when melted in air and when melted in a vacuum induction furnace.

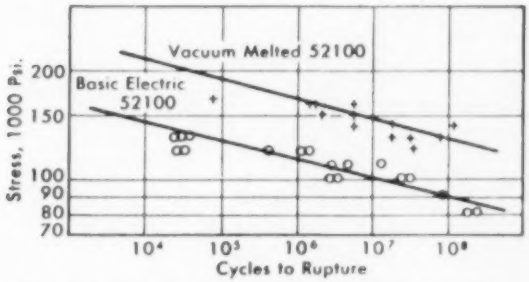

Fig. 4—Log-log plot showing cycles to rupture in standard fatigue test of basic electric furnace steel 52100 versus the same steel, vacuum induction furnace melted.

ingot consumably melted shows a spread of 0.05 pct Mo and 0.08 pct Ti, a conventional ingot of comparable cross-section would show a spread of about 0.30 to 0.50 pct Ti. Homogeneity in titanium is particularly desirable in A-286 alloy, since its strength is gained through the precipitation of Ni_3Ti.

Improvement in sulfur segregation is also achieved by consumable-electrode, vacuum melting. This is illustrated in Fig. 10 for a low-alloy steel containing 0.045 pct S.

Since air-melted electrodes are consumably remelted in a copper crucible which prevents refractory contamination, and since melting progresses in a vertical direction, inclusions are removed not only through the vacuum melting itself, but also through the process of levitation which permits the floating out of the more stable inclusions. The improvement in the cleanliness is shown in Table II for a low-alloy steel, a bearing steel, and two grades of stainless steel.

Reduction of gas content is also an important factor in consumable vacuum melting. Typical degassing of several superalloys that can be obtained through consumable-electrode vacuum remelting is shown in Table III.

Table III. Decrease in Gas Content on Consumable-Electrode, Vacuum Remelting

Gas Analyzed	Alloy	Air-Melted Electrode, Ppm	Cons Elect Vac Melt, Ppm	Decrease, Pct
Hydrogen	Waspaloy	17.7	2.2	88
	M-252	16.0	1.7	89
	A-286	13.1	2.8	79
Oxygen	Waspaloy	31.0	2.0	94
	M-252	15.0	6.0	60
	A-286	13.0	5.0	62
Nitrogen	Waspaloy	420.0	120.0	71
	M-252	160.0	40.0	75
	A-286	300.0	20.0	93

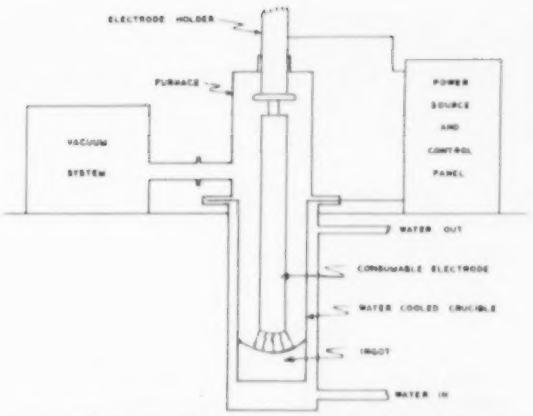

Fig. 5—Consumable-electrode, vacuum remelting furnaces can produce larger ingots with less segregation than can vacuum induction furnaces.

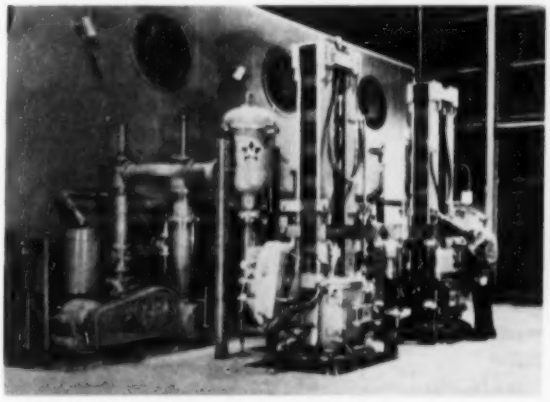

Fig. 6—The first consumable-electrode, vacuum remelting furnaces were installed at the Watervliet Works of Allegheny Ludlum Steel Corp. in 1955.

Advantages and disadvantages of induction vacuum melting

1) Improves mechanical properties;
2) Eliminates gases, making very high purity melts possible;
3) Affords very close control of composition; this has opened up many new fields in superalloy research;
4) Does not remedy solidification and segregation problems, thereby limiting ingot size; and
5) Is the more expensive of the two processes.

Advantages and disadvantages of consumable-electrode vacuum arc melting

1) Improves mechanical properties;
2) Eliminates gases, making very high purity melts possible;
3) Eliminates or minimizes segregation;
4) Affords homogeneity in mechanical properties and chemical composition in large ingot and billet sizes, and in alloys containing high-density elements; and
5) Is lower in cost than induction vacuum melting.

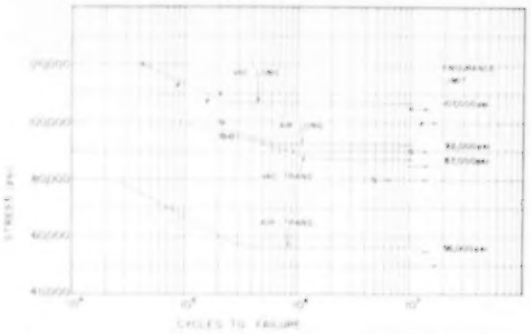

Fig. 7—A comparison of transverse and longitudinal fatigue strength of air-melted and consumable-electrode, vacuum-remelted SAE 4340 billets.

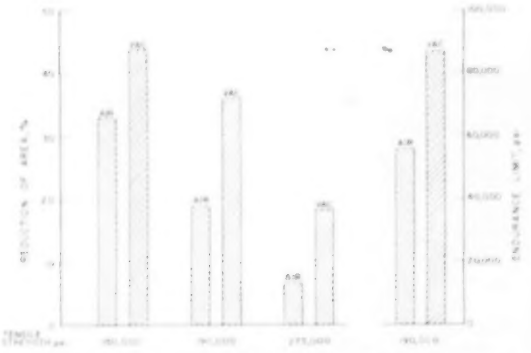

Fig. 8—Transverse properties of air-melted versus consumable-electrode, vacuum-melted SAE 4340 billets.

A quick survey of specifications for vacuum melted materials readily reveals the higher quality requirements that are being imposed. Both induction vacuum melting and consumable-electrode vacuum melting have made significant strides in providing materials with improved metallurgical properties for critical applications. Both of these processes have firmly established themselves in the specialty steel industry, and will continue to grow as the demand for premium quality materials increases. The extent to which each will be used will be determined by the properties required by the design engineer, and the extra costs incurred in producing higher quality alloys.

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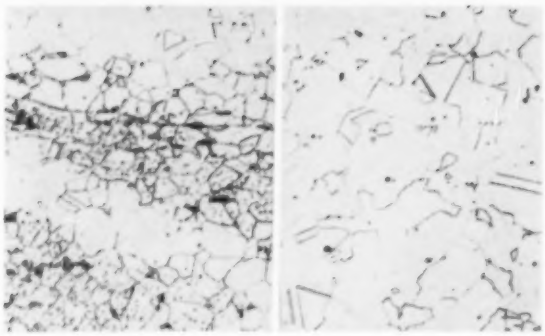

Fig. 9—Microstructure at center of jet-turbine wheel forgings made from 9-in. sq billets of A-286 alloy. Magnification 100X.

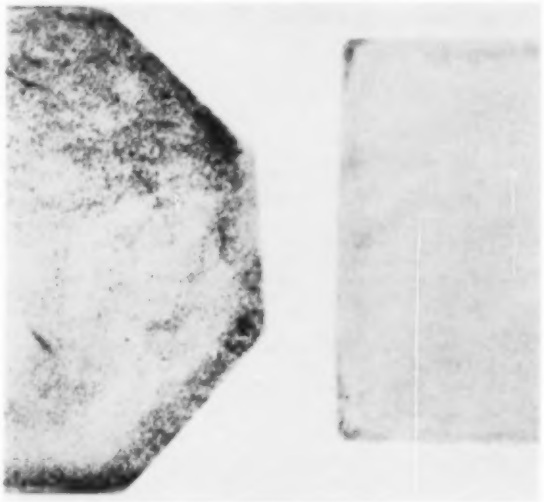

Fig. 10—Sulfur prints of billet cross-sections of a Ni-Mo-V low-alloy steel. At left 10-in. octagon air-melt; at right, 9-in. sq consumable-electrode, vacuum remelt made from air-melt.

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Summarized from an article by Rene Perrin,

with notes on the Ugine plant by F. Weston Starratt

LADLE SLAG-REFINING OF ELECTRIC FURNACE STEEL

Striving to increase steel output per furnace as well as to improve steel quality, one of the leaders of French electric-furnace steelmaking—Ugine—has perfected a ladle slag treatment for rapid desulfurization and deoxidation. The result: tap-to-tap time reduced by more than 50 pct, and output per furnace increased by more than 200 pct. René Perrin, who developed this technique, also points to the possibility of applying slag treating practice to increase output of other steelmaking furnaces as well as the blast furnace.

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High in the French Alps near the Swiss border is the town of Ugine with its alloy steel plant, one of France's largest—below.

ORIGINAL installation of the Heroult electric-arc furnace for steelmaking occurred in the mountainous French alpine region of Savoie where use could be made of the hydroelectric potential which the area offered. At the small town of Ugine, surrounded by towering snow-capped Alps, installation was made of a small electric-furnace shop for the production of ferroalloys in 1903. Steelmaking was undertaken in 1907, and by 1914 there were eight 5-ton arc furnaces in the plant. In 1921 the Société d'Electrochemie, d'Electrométallurgie et des Aciéries Electriques d'Ugine was formed as an amalgamation of the Ugine plant with a number of felloalloy plants and electrochemical firms in Savoie. Since that time the firm has been one of the leading French producers of alloy steels and ferroalloys as well as a wide number of nonferrous metals and chemicals.

Ugine, producer of quality steels at high output rate per furnace

The Ugine plant produces some 10,000 metric tons per month of more than 100 different alloy steels. Large tonnages of ballbearing steels are produced that should be devoid of any internal defects however small, and should meet extremely severe physical and chemical specifications. High purity is also essential for other Ugine products, such as razor-blade steel and structural steel which, moreover, must have excellent transverse physical properties and weldability and be devoid of internal defects. That is why regular production shows particularly low sulfur content: below 0.010 pct, and for high carbon steels on the order of 0.005 pct. But only commercial grades of common scrap are used to manufacture these fine steels, and this scrap has a comparatively high sulfur content. Much research work has, thus, been expended in perfecting techniques for producing low-sulfur steel from this high-sulfur raw material.

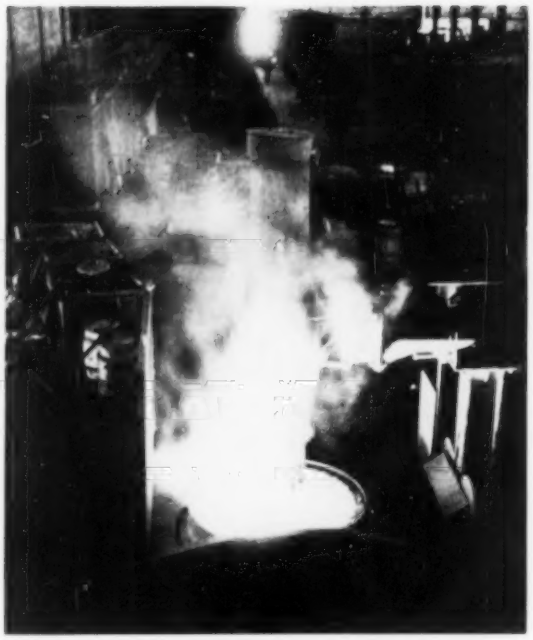
Because of the heavy capital outlay required for steelmaking equipment it has long been the policy of Ugine to increase the yield of large existing fixed assets by adding small ones, and to minimize the amount of fixed assets for new plants.

At Ugine steelmaking is carried out in three basic-lined arc furnaces: one of 40-ton capacity, one of 30-ton, and a third of 15 ton. A comparison between the capacities of these furnaces and the plant's monthly output of more than 10,000 metric tons of steel reveals the basic factor in the economics of production, namely the low tap-to-tap time. While as much as 7 hr might be required in similar operations, the slag refining technique developed at Ugine permits less than 3 hr tap-to-tap time. This is due to the technique used, for in the Ugine arc furnaces only decarburization, dephosphorization, and alloying are required, while refining takes place in the ladle after the furnace has been tapped. In addition, an oxygen lance may be used in the case of high-carbon or high-phosphorus charge in order to speed-up these reactions.

The Perrin slag treatment process

The process which is responsible for this speed-up as well as the production of low sulfur steels, is the slag treating technique developed by Ugine's Director-General, René Perrin.

In this process metal is tapped from the furnace into a ladle containing slag especially made to accomplish desulfurization and deoxidation. The necessary chemical reactions take place rapidly due to the large interface between the metal and the slag caused by the heavier metal being poured into the liquid slag. An important factor in carrying out the reaction is a low slag viscosity which can be closely controlled through slag composition and temperature. Furthermore, the metal must be as clean as possible; thus, prior to tapping, a furnace slag is first removed, and the steel is poured at temperatures between 1500° and 1600°C. The Perrin slag in the ladle is some 50° above this temperature.

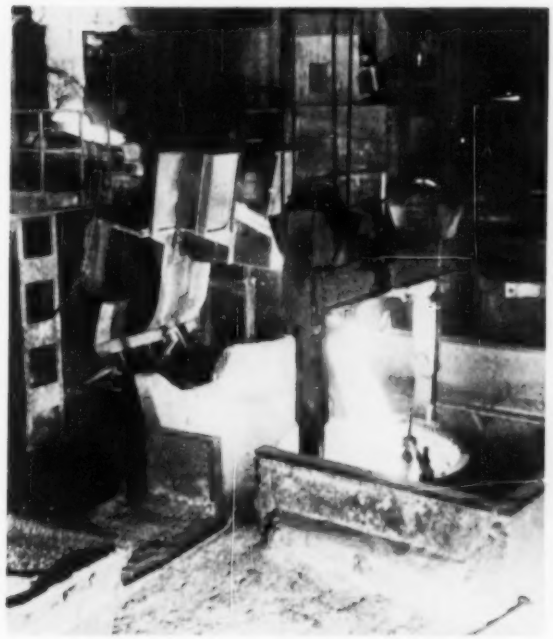


First . . . . alumina and lime melted in arc furnace

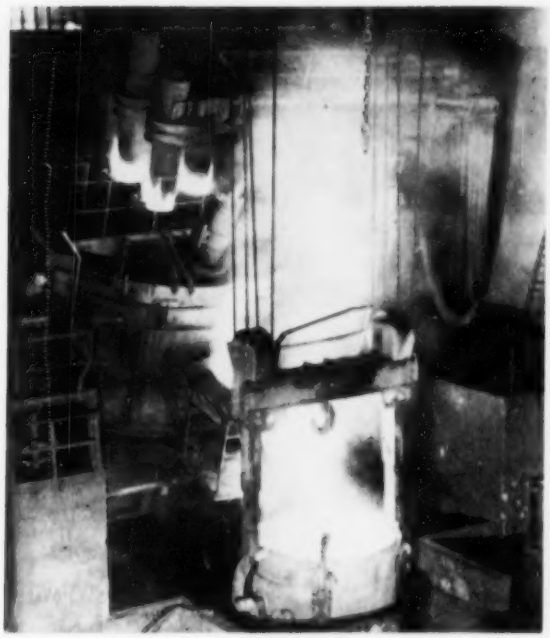
Desulfurization-deoxidation slag for killed steels

The Perrin desulfurization-deoxidation slag is a high-lime, high-alumina slag of the following general composition: 42 pct Al_2O_3, 53 pct CaO + MgO, less than 5 pct SiO_2, and less than 1 pct FeO. The basicity of such a slag precludes its use in the arc furnaces at Ugine which are either acid-lined or basic-lined with a roof of silica refractories. Any treatment with such a slag must, therefore, take place in a basic-lined ladle.

The Perrin slag, which must be low both in iron oxides and silica, is made by fusing alumina and lime; however, it has been found possible to melt a low-silica, iron-bearing bauxite with lime and excess coke to produce metallic iron together with the alumina-lime slag. At Ugine, raw materials per metric ton of slag are as follows: 470 kg of alumina or bauxite from which the iron has been removed, and 570 kg of lime. Alumina and lime are melted in arc furnaces, which have walls cooled so as to cause the formation of a protecting layer of slag. These lower-power, small-capacity slag furnaces are operated on single-phase current; they have eventually no roof, protection against heat radiation being assured by the cold charge. The fused slag, which is poured into a ladle at temperatures between 1600°



Second . . . . slag poured into ladle at 1600°C



Then . . . . steel poured into same ladle

The result . . . . rapid desulfurization and deoxidation of steel.

and 1700°C, amounts to between 2 and 5 pct of the weight of the metal.

The deoxidation action of the slag requires that the tapped steel contain 0.2 pct Si more than the aimed silicon content of the steel. Such silicon may be carried into the liquid steel from silicon-containing scrap or pig iron, or from ferro-silicon or metallic silicon which may be added to the steel in the arc furnace. The deoxidation action of the slag is greater as its alumina content is increased. With alumina-rich slags, there is a partial reduction of the alumina by the metallic silicon in the steel and introduction of small quantities of aluminum into the steel. This metallic aluminum serves as a reducing medium for all other metallic constituents in the metal bath, and this assures a high degree of metal purity and freedom from inclusions. If the alumina content of the slag is reduced, while the silica content is increased, then the intensity of desulfurization, as well as deoxidation declines rapidly. In order to ensure proper deoxidation and desulfurization, the metal must carry with it little or no entrained silica from the arc furnace slag.

Although one single operation does not exhaust the slag's power to deoxidize and to absorb sulfur, this slag is not used twice at Ugine, because of the quality of the steel products desired. The used slag is of such composition that it can be used for cement production.

The desulfurization action of the slag, which depends largely on its high free lime content, is governed by the following reaction:

$$FeS + CaO = FeO + CaS.$$

This reaction proceeds rapidly when the slag is sufficiently low in iron oxide, which is the case with the freshly prepared slag. In addition, the deoxidation action of the slag, described above, ensures a low FeO content of the metallic bath, which further increases the extent to which the desulfurization reaction proceeds.

Most dephosphorization is carried out in the arc furnace through normal furnace procedure, speeded-up by use of the oxygen lance where necessary.

Slag to eliminate phosphorous and silicon

Through research work in slag chemistry carried out by Ugine, various slags have been produced for the purpose of eliminating deleterious elements encountered in steelmaking practice.

An example of these slags, is one made of CaO and FeO which has proven effective in reducing the phosphorus and the silicon contents of killed and rimming steels. Because of its desiliconizing effects, this slag has proven particularly useful in refining pig iron in the electric furnace. In addition, the slag's high lime content has a positive effect on sulfur elimination. Its dephosphorization qualities depend on the following reactions:

$$5\,FeO + 2\,Fe_3P = P_2O_5 + 11\,Fe$$
$$4\,CaO + P_2O_5 = (CaO)_4P_2O_5$$

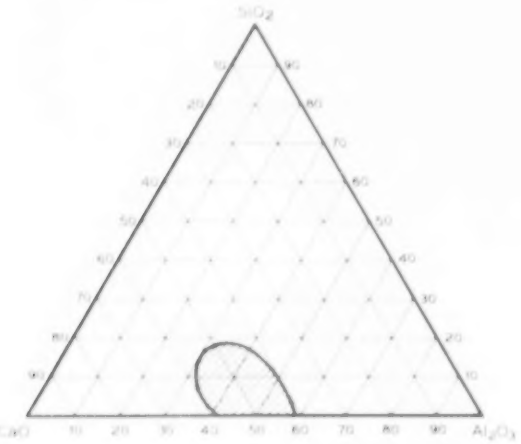
Slag treatment for blast furnace

Slag treating techniques for the elimination of sulfur and other deleterious elements have application beyond the steelmaking furnace. Ugine's operations are based upon scrap as a raw material, and naturally interest by the firm is focused on their own production problems, but recently Ugine's research laboratories have done sufficient research work on slag treating techniques for liquid pig iron, to lead to the conclusion that such slag treating practice would be of importance to blast furnace operators.

To increase output from existing furnaces

Looking at the iron and steel industry as a whole, there is no doubt that the sulfur and phosphorus problem has a most important bearing on equipment and production costs.

As regards iron for the open hearth, blast furnace operators aim at a low sulfur content which requires the addition of large amounts of limestone to produce a basicity index of about 1.3. In spite of rich ore used in many furnaces, the relatively high slag throughput reduces blast furnace output. Moreover, it increases coke consumption, since the heat required to melt slag is much greater than that needed to melt iron.



Composition scope of the most frequently used alumina-lime slags for the Perrin desulfurization-deoxidation process for electric furnace steels.

The legitimate question thus arises as to whether it would not be more economic to produce iron with a higher sulfur content, even in basic operations, so as to increase blast furnace output, and then to desulfurize by auxiliary means. The latter requires fixed assets which are low in comparison with the fixed assets entailed by subjection to sulfur.

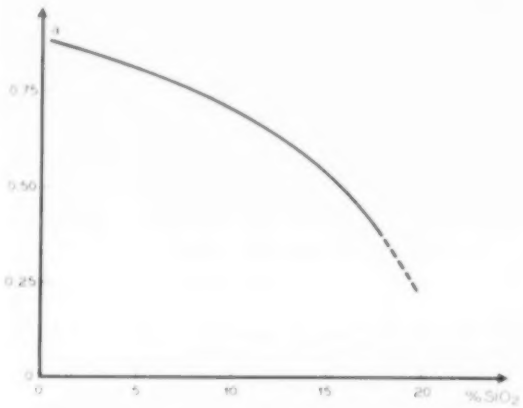
There are several methods for desulfurizing iron with molten slag: one of them uses a special slag based on fluorspar and lime, selected, on the one hand, because of its high desulfurizing power, and on the other hand, because its melting point is much below the tapping temperature of iron. An adequate composition of this slag is the following: 30 pct CaO, 65 pct CaF_2, and 5 pct SiO_2. To prevent the slag from freezing, slag weight should not be lower than 2.5 pct of the iron weight. With such an amount of slag, it is easy to eliminate ¾ of the sulfur content of the iron, which is enough for practical purposes. The operation can be carried out in the ladle into which slag has previously been poured or during the pouring of the metal into the ladle. This slag can be added in the solid state.

Desiliconizing and desulfurizing iron

There is also interest in regularizing the silicon content of iron, because peaks in silicon content result in production cost increases and in off-grade heats on conversion to steel. But it is particularly difficult to obtain regular silicon contents when using high-grade ores, because the amount of slag formed is not sufficient to regulate blast furnace operation.

Extensive experiments have been conducted to bring the silicon content of iron to within acceptable limits by oxygen blowing, but in this operation appreciable amounts of iron and manganese are burnt. Such an operation can be followed by a desulfurizing process, but this means two successive operations to be conducted on iron.

Monsieur Perrin of Ugine has had the idea of effecting desiliconizing and desulfurizing in one operation, with a single slag, by extending the time during which iron and slag are mixed together. The principle is to use a molten slag essentially composed of lime, some alumina, and iron oxides. In the initial stages of the mixing operation, iron and manganese oxides are almost completely reduced by silicon, and the slag is then composed of SiO_2, Al_2O_3, and CaO. If the original composition has been carefully calculated, the final slag is fluid, and continued mixing results in desulfurization. Ugine thoroughly checked this principle experimentally, but not being



Desulfurizing power as a function of silica in slags for the Perrin slag treatment process. The desulfurizing power of the slag—measured on the ordinate—is characterized by the value of "a" in the formula, $\Delta s = aS_i - 0.004$ pct. The alumina:lime ratio is assumed to be constant.

iron makers, Ugine's experience has been limited to pilot-plant tests. These tests have been conclusive, and a commercial-scale plant is now being designed.

To put this desiliconizing-desulfurizing slag technique into practice would require only a slag furnace and a mixer. It is an exothermic process. If a normal blast furnace slag is selected as final desulfurizing slag, about 1 pct of initial slag will be required per 0.1 pct Si removed. This amount varies according to the ratio, Fe_2O_3:FeO in the slag; it is lower when the ratio is high. Contrary to oxygen blowing, there is a definite recovery of iron, and possibly of manganese.

Conclusions

Molten slag treating techniques are an element which makes it possible to reduce considerably the amount of investment per ton of steel produced, with correlative improvement in the overall production costs.

Besides striving to make the best quality steels, Ugine has had as a basic policy: to increase the yield of heavy existing fixed assets by adding small ones, and to minimize the amount of fixed assets in new plants. The Perrin slag processes have accomplished these goals with the electric furnace and preliminary investigation shows that such type of treatment is equally applicable to the blast furnace.

by J. D. McCullough

CASE STUDIES IN CAST AND RAMMED ARC-FURNACE ROOFS

Monolithic constructions in center sections of arc-furnace roofs have proven a practical method of reducing refractory roof costs, offering maximum economies when either rammed or cast. Avoiding laminations and insuring volume stability of the material are important considerations, and materials and methods are available to accomplish this.

REDUCTION of refractory costs in roofs of electric arc furnaces has been a subject actively pursued by most operators. This paper is concerned primarily with describing results obtained in several plants where monolithic constructions have been successfully employed in the roof.

Types of refractories

The common denominator in each of the four electric furnace cases covered was a comparison of fired refractory shapes versus monolithic constructions. In some cases the fired refractory was standard series brick and in others special shapes.

The monolithic refractories were of three different types: 1) Plastic refractories ranging from approximately 45 pct alumina, having a density of about 140 lb per cu ft, up to 70 pct alumina, having a density of approximately 165 lb per cu ft; 2) Ramming mixes ranging from 65 to 83 pct alumina and with densities on the order of 175 to 180 lb per cu ft; and 3) Two castable refractories: one, volume stable to 3000°F, containing approximately 60 pct alumina with a density of approximately 125 lb per cu ft, and a second, volume stable to 3200°F, containing approximately 66 pct alumina with a density of approximately 135 lb per cu ft.

Case I—A southern steel plant

This plant has two 18-ft, 76-ton furnaces producing mainly plain carbon and semi-killed steel ranging from 0.04 to 1.00 pct C. Basic, single-slag practice is used, with decarburization being done with metallurgical oxygen. The brick construction was of 13½ in. silica brick throughout, and average roof life was 60 heats.

Experience over a period of two and a half years, with 3000°F castable refractory around the electrode ports, indicated that use of the castable increased average roof life from 60 to 80 heats. When the roofs were removed from service, the castable refractory projected 1 or 2 in. beyond the adjacent silica brick.

The plant changed from silica brick to superduty clay brick retaining the castable refractory around the electrode ports, and this increased roof life to about 100 heats, with no patching. Again, roof life was determined by brick limitations.

The method of forming the ports is quite simple. A metal core of 22 in. diam is appropriately located to form the ports when the castable is poured. Silica brick are laid up in complete rings until they come within about 6 in. of the cores. Three partial rings are then laid between the ports, leaving a 6-in. space between the brick and the core. After the third partial ring is laid, the brick are then laid at right angles to their former direction and carried in this manner up to the center of the roof, where the three *spokes* meet to form a triangle. This triangle is also filled with the castable. This procedure eliminated time-consuming cutting and fitting.

At this plant the dry castable is mixed with approximately 16 pct water to permit easy placement. This is a somewhat higher percentage than is desired for maximum strength, but since the resulting refractory is superior to the surrounding brick, there has been no necessity to investigate improvements by reducing the water content. Approximately 2400 lb of castable is used in each roof.

Curing is accomplished by placing wet sacks on the castable after it has taken its initial set and keeping them on overnight. The roof is then allowed to air dry until it is placed on the furnace, which may be from 24 hr to a week later. No special heating precautions are followed on the initial heat of a new roof.

Roofs constructed entirely of silica average 128 man-hr versus only 54 man-hr for roofs using a castable refractory in the electrode area. Although the castable has a higher cost per cu ft than the

J. D. McCULLOUGH is Chief Engineer, Refractories Div., Babcock & Wilcox Co. Paper to be presented at the AIME Electric Furnace Steel Conference, Pittsburgh, December 1957.

Fig. 1—A roof prepared for casting of electrode ports and center.

silica brick, the total installed cost of roofs with the castable, because of savings in labor, was about 7 pct lower than a roof of brick only. Because of the greater life obtained on roofs with castable electrode ports, plus the lower installed cost, the refractory roof cost per ton of steel has been reduced by 30 pct.

Case II—Manufacturer of tubular products in Pittsburgh area

This plant has one 16 and one 18-ft diam furnace, producing 54 and 75 tons heats of low-alloy (less than 5 pct Cr) steel. Basic, two-slag practice is used, and the 12-in. silica brick formerly used averaged 54 heats.

Initial trials of monolithic construction were with a ramming mix. Silica brick were used to form the electrode ports. The brick forming the roof were then brought up to about 12 in. from the port rings, which resulted in constructing partial rings between ports to maintain this 12-in. space which was then filled with a ramming mix, using an air rammer having a 4½ in. round head. The first four roofs gave no additional life, failure being by spalling. Changes in consistency and ramming method did not succeed in eliminating the spalling nor in improving roof life. The primary difficulty resulted from laminations produced by ramming.

It was found that there was a savings of approximately 24 man-hr of installation time by ramming instead of by fitting brick. Because of the higher cost of the ramming mix as compared with silica brick, the installed costs were about the same, even with a reduction in labor.

The next step was to try a 3200°F castable. This material was used in the same location as the ramming mix except that the space to be filled was reduced from 12 to 6 in. Instead of ramming the castable refractory, it was placed by means of a high speed internal vibrator having a 1¾ in. diam head and a frequency of 12,000 vibrations per min. The mix was relatively dry, only 12 pct water being used, but the action of the high speed vibrator quickly reduced the consistency to one which flowed readily. Installation time was 40 man-hr less than when cutting and fitting brick.

The first two roofs so installed averaged 64 heats as compared with 52 heats on silica brick. A roof was then tried in which the ports were cast directly in the same manner as Case I. This roof gave life of 68 heats.

Encouraged by these results, the operators tried the castable refractory above the skewback line on the mast side, where failure of silica brick was reducing roof life. This section extended about 8 or 9 ft in length and the width of four 4½-in. rings of brick. Two or three ribs of brick were placed in this length about 30 in. apart. The results were very encouraging, and further experimenting is continuing. A mullite-type brick was then used to form the electrode port, and the roof life was increased to an average of 74 heats. As of September, 1957, some further testing was being carried on to form skewbacks of this castable in the area where the patches were being used successfully. Initial results have proved that this application offers definite promise. No special drying or firing procedures are followed.

The present construction with the 3200°F castable has about the same installed cost as an all silica-brick roof, but because of improved life the

Fig. 2—The top of the roof, showing completed ports and center of castable refractory.

Fig. 3—The same roof as shown in Fig. 2, as viewed from the bottom.

Fig. 4—The castable is here shown being vibrated around the electrode port brick.

cost of roof refractories per ton of steel has been reduced by 20 pct.

Case III—A steel company

This plant has a 20-ft diam furnace with 85 ton capacity and produces primarily high chrome-nickel alloys of the 300 series. Basic, two-slag practice is used, and metallurgical oxygen is used for decarburization. Eighteen-inch silica brick were formerly used, with heat life averaging 43 heats on steady operation.

This shop changed to 13½ in. thick 70 pct alumina brick in the roof, and because of greater difficulty in cutting and fitting high-alumina brick in the center section, bricklaying time was increased by 50 to 60 man-hr. In order to reduce installation time, a 3200°F castable refractory was tried around the electrode ports.

On the initial installation, the electrode port was formed of 18-in. long by 6-in. wide arch brick of the same type as used in the roof proper. Brick were laid within 4 to 5 in. of the port ring, similar to the construction illustrated in Case II. However, from the last ring a pier was extended to the electrode port rings because the masons feared the possibility of the rings slipping out. The 3200°F castable was vibrated in the space remaining around the electrode ring brick. A total of 2300 lb of castable with 11 to 12 pct water addition was placed by three men in a total of 6 man-hr, using a high-speed internal vibrator. The cost of the castable material was approximately equal to the value of the brick which it displaced. No special curing provisions were made.

The first two covers so installed gave 48 heats and 55 heats during a period of slow, intermittent operation. Roof life was limited by erosion of the brick forming the electrode ports. The castable refractory extended beyond adjacent brick when the roofs were removed from service.

Another roof constructed in the same manner was in operation at the time this paper was being prepared, and had not completed its useful life. It is not certain that the piers are necessary which extend to the electrode port brick. This belief is borne out by the success at other plants where roofs without piers have performed successfully. It is planned, however, to try several variations of castable and brick in the electrode section.

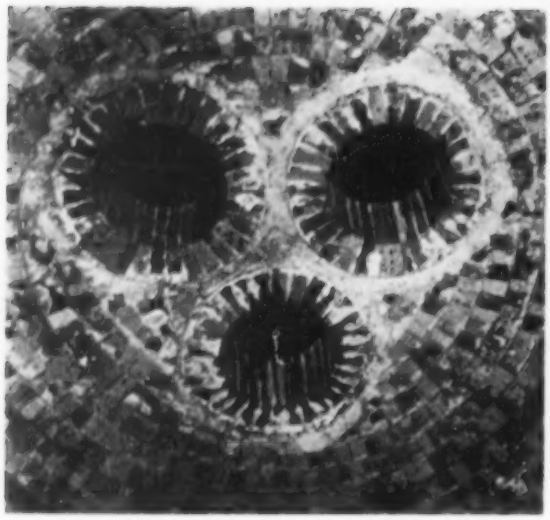
The immediate objective of saving approximately 50 man-hr on installation time was attained without prejudice to roof life, and at no extra material expense.

Case IV—A midwest forging company

This plant has two 13-ft furnaces producing heats that average 36 tons. Top charging and basic, two-slag practice are used, with oxygen introduced both for melting and decarburization. Up to 5 pct Cr and 4300 series alloys are produced. Formerly, 12-in. superduty fireclay brick were used, giving an average of 70 heats.

Although special center shapes had originally been used for the purpose of simplifying brickwork installation in the roof centers, experience did not

Fig. 5—The top of a completed roof, showing castable around the port rings. Detail of the brick work is also visible.



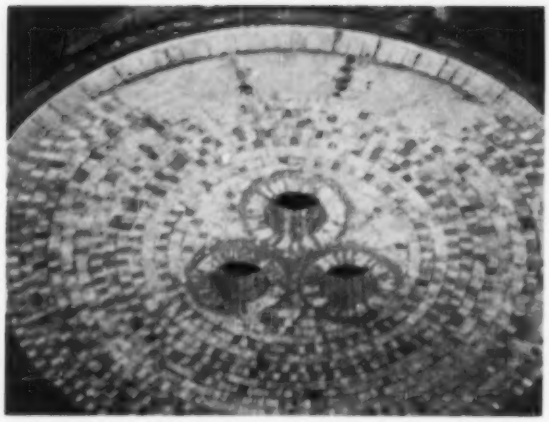


Fig. 6—Left: The same roof as shown in Fig. 5, as viewed from the bottom.

Fig. 7—Above: Another view of the same roof shown in Fig. 5, showing the castable sections near the skew.

justify this expectation. Because of roof rings getting out of round it was found necessary for two men to spend a total of 48 man-hr per roof to cut and fit the special shapes.

Various monolithic materials were tried, including two types of ramming mixes, two types of plastic refractories, and two types of high-temperature castables. As of August, 1957, a total of 16 roofs had been installed by ramming and one had been installed by casting. Of these roofs, 13 were constructed with superduty fireclay brick forming the main portion, two with silica brick, and one with a 70 pct alumina brick. In all cases except one, the electrode ports were formed with high-alumina brick of the 15 x 6 x 3 in. series, either with straight or corrugated backs.

The roofs were constructed by bringing full rings of 12 x 6 x 3 in. series brick to within about 6 in. of the outside of the rings forming the electrode ports. There were no partial rings built up between ports. Thus, there was a section of monolithic refractory in the center, aproximately 6½ ft OD on the top side tapering to about 5 ft 9 in. on the bottom, containing the three rings of electrode brick.

Approximately 22½ cu ft of material was required for each center section. Installation time for a three-man crew using an air rammer took a total of 18 man-hr.

Failure of the rammed roofs was apparently brought about by lamination tendencies, which appeared to be similar in effect with all the materials used. Failure by spalling would normally start before ten heats, in an area about 1-ft in diameter next to the last ring of brick. This pattern would then be followed in another area, and the action would continue with successive layers being lost until the roof required removal.

Roof life ranged from 62 heats with the 3000°F castable refractory up to 87 heats with the 3200°F castable. A 70 pct alumina plastic refractory averaged 86 heats. These results were eight to ten heats better than a superplastic and an 80 pct alumina ramming mix, and about 18 to 19 heats better than a mullite-type ramming mix.

In addition, one roof of the 3200°F castable was installed with the electrode ports formed directly in the castable similar to Case I. This roof gave a life of 76 heats, failure again being attributed to the effects of lamination brought about by ramming.

An installation was made of the 3200°F castable by means of a high speed vibrator, as described in Case II. A crew of five men installed 3000 lb of the castable in a total of 7½ man-hr. Water content was maintained at about 12 pct. Mixing was performed by hand in two-bag batches with two batches mixed simultaneously. It was estimated that with a four-bag mortar mixer a four-man crew could complete the installation in 1 hr.

Following placement of the material, wet sacks were placed on the castable after it had taken its initial set and they were kept there for 24 hr. A day later the roof was placed on the furnace and heated with a gas torch for 2 days. No special heating precautions were followed on the first heat. This heating schedule is standard for all monolithic roofs. As of 50 heats, there was no indication of the laminations characteristic of the rammed roofs.

The cost per heat of roofs with rammed centers of the 3200°F castable was reduced by approximately 15 pct as compared with roofs constructed with the special center shapes of fired tile; likewise a savings of approximately 5 pct was obtained as compared with the 70 pct alumina plastic which showed up next best. Although the difference in life between the two materials was negligible, the plastic had a higher first cost due primarily to the greater quantity required because of its higher density.

Should the final results indicate that the castable, when vibrated into place, gives a life equivalent to ramming, additional savings will result because of reduction in placement time. Further savings would result if a longer life were obtained.

Discussion

The four plants covered in the foregoing cases are typical of many which are successfully using monolithic constructions. The results listed indicate that in all cases the use of monolithic refractories permitted savings in refractory roof costs, ranging up to 30 pct. They also indicate that there is a variation in results among different materials and that the method of installation can have a significant bearing on the refractory life and the resultant savings in costs.

by J. H. Kogen

ANALYSIS OF ARC FURNACE CONTROL

A method has been devised for working out problems in arc furnace control, either on paper or with the aid of a computer, which eliminates costly guesswork in choosing components, making adjustments, and modifying control systems.

THE progress in automatic control in the past few decades has been aided considerably by development of methods for analyzing the control systems. With this knowledge, means for improving and optimizing the system can be evolved. In essence, the design of the equipment will be based more on fact and less on extrapolation or chance.

The arc furnace presents a problem of continually changing conditions. Temperature, the materials being melted, and many other things vary the parameters of the system, and the analysis must consider the range of conditions encountered. For this reason an approximate analysis is of value, although a comprehensive analysis of all the various complexities will undoubtedly provide additional information. For practical design considerations, certain reasonable assumptions and approximations are acceptable, but it must be appreciated that the analysis is only applicable within the boundaries of these approximations.

Description of system

The arc furnace control system is shown diagrammatically in Fig. 1. Arc current and arc voltage are measured by means of current and potential transformers. These two measurements are sent to a controller which compares the two values and produces power for the hydraulic cylinder or electric motor actuator. The actuator is mechanically coupled to the electrode mast and positions the electrode until the desired balance between current and voltage is obtained.

Analysis

The first step in the analysis is to represent the furnace in a simple block diagram form as shown in Fig. 2. A mathematical notation is normally employed which completely describes the operation of each of the components. This description is made in two parts: the input-output characteristic and the dynamic characteristic.

The input-output characteristic, normally called *amplification* or *gain*, is the ratio between what comes out and what goes in. An electronic amplifier might produce an output of 100 v for an input of 10 v for a gain of 10 v per v. A dc motor might rotate at 1000 rpm when 100 volts is applied to the field, the gain then being 10 rpm per v. If the output of a gear train is 1 revolution when the input has turned 20 revolutions, the gain is 1/20.

Each component in the system, then, has a gain value by which it is partially described, and this value is not a function of time. If the input to a device is changed instantaneously, the output may not change as rapidly.

The dynamic characteristic

The second part of the description of the element is the dynamic characteristic. This takes into account those factors which are a function of time. Among these factors are: inertia, spring rate, viscous damping, inductance, resistance, and capacitance. This description is normally in the form of a type of shorthand notation derived from the differential equations which describe the component.

Using the mathematical descriptions of each component, the operation of the control system is simulated by an electronic computer or by mathematical analysis. The ease of performing this operation as compared to building the entire apparatus is apparent, particularly when the apparatus is as enormous as the larger arc furnaces.

Most of the commonly employed components such as electric motors, hydraulic cylinders, transformers, gear trains, and so on, have been thoroughly analyzed and can be described mathematically with

J. H. KOGEN is Chief Development Engineer for the Askania Regulator Company, Chicago. Paper to be presented at the AIME Electric Furnace Steel Conference, Pittsburgh, December 1957.

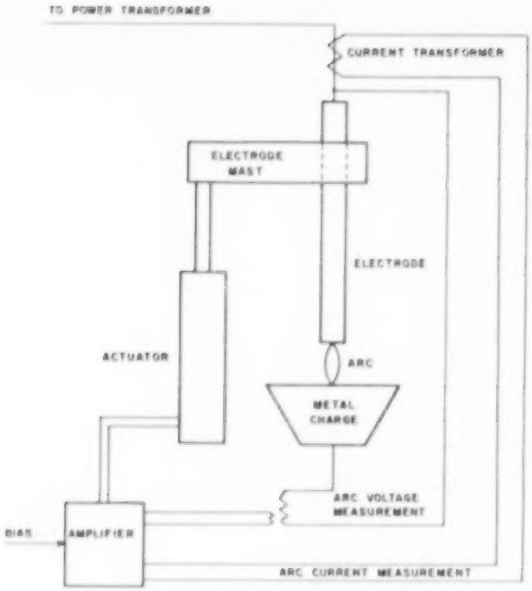


Fig. 1—A typical system for electrode control.

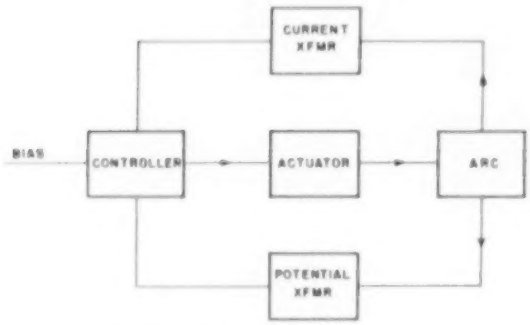


Fig. 2—Block diagram of the elements in an electrode control system.

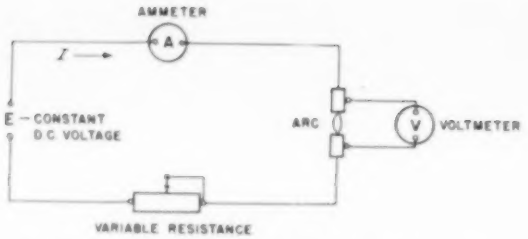


Fig. 3a—Circuit for measuring the arc current-arc voltage relationship of the dc arc.

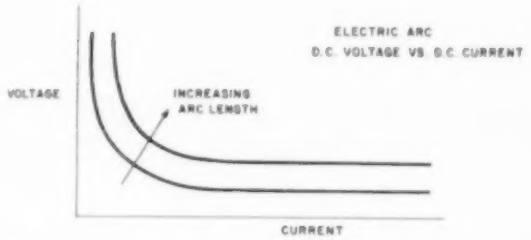


Fig. 3b—Arc current-arc voltage plot for constant arc length.

Fig. 4a—Half cycle ac wave superimposed on dc characteristic.

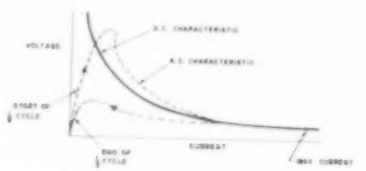
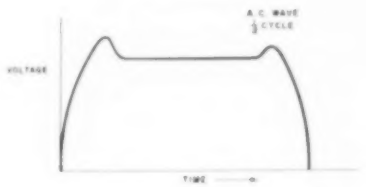


Fig. 4b—The ac wave on a time basis.



considerable accuracy. In analyzing the electrode control system, the main problem is that of accurately describing the arc itself.

Analysis of the furnace arc

In the electrode control system a measurement is made of arc current and/or arc voltage. These variables change as the arc length changes. Thus, the gain of the arc is the arc-volts per unit arc length and arc-current per unit arc length. With all other parameters constant, it is necessary to determine the change in arc voltage and arc current for a unit change in arc length.

The dynamic characteristic of the arc describes the time lag involved after a change in arc length, until new values of current and voltage are reached, but for the purposes of this discussion it will be assumed that this lag can be ignored. Such factors as the inductance between electrodes and the ionization time of the gases are assumed negligible compared to other factors in the control system.

To determine the gain characteristic, we will first consider the direct current arc. Fig. 3a shows a circuit which would be used for measuring the arc current-arc voltage relationship of the dc arc. Voltage E represents a constant dc source. Current I is controlled by varying the resistance in the circuit. The voltage is measured across the arc; the ammeter measures current through the arc, and readings are taken for various settings of the series resistance. Fig. 3b shows a plot of such readings for a constant arc length. When the current reaches values in the order of thousands of amperes, this characteristic becomes relatively flat, arc voltage remaining constant for increasing values of arc current.

Consider now ½ cycle of an alternating current wave. Such a wave is shown superimposed on the dc arc characteristic in Fig. 4a. At zero time the current and voltage are both 0, and no arc exists. The voltage in the circuit increases until point A is reached, at which time the arc strikes. The voltage then falls to some value near the dc arc characteristic. As the applied voltage increases, the ac arc characteristic follows the dc arc characteristic until some large current value where the two are practically together. The current increases until some maximum point is reached and then begins decreasing. The current decreases following the dc characteristic until some low current value is reached, at which time a slight increase of voltage occurs and then the arc extinguishes. The voltage then follows the applied voltage curve down to 0.

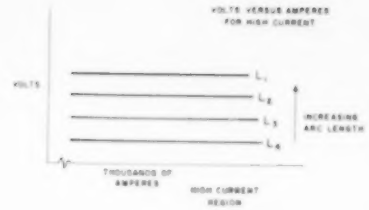


Fig. 5—Arc voltage vs arc current for various arc lengths.

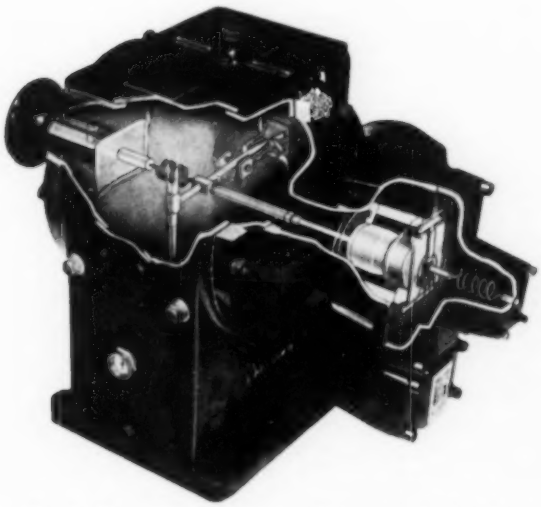


Fig. 7—The moving coil element which moves the jet pipe shown in Fig. 6.

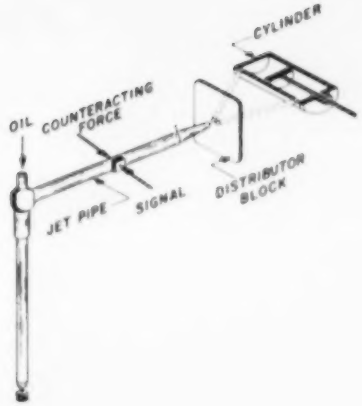


Fig. 6—The jet type of electrohydraulic controller.

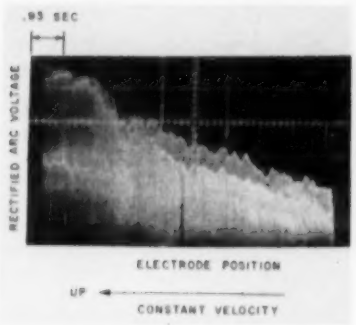


Fig. 8—Arc voltage vs electrode position, as measured by the oscilloscope.

Fig. 4b shows the ac wave on a time basis, portraying a small peak at the beginning and end of the half cycle and the relatively flat top during the majority of the half cycle.

To simplify the analysis, the voltage wave will be approximated by a square wave; this approximation means that the small portions at the beginning and end of the half cycle are being ignored. For large values of current this is a reasonable approximation.

Fig. 5 is a set of curves showing arc voltage versus arc current for various arc lengths in the high current region. Since the distance between these curves is independent of current, a plot can be made of arc voltage versus arc length. The slope of this curve is arc-volts per unit arc length or arc voltage gain. Tests made by various observers show that the value of arc voltage gain is in the order of 10 to 30 v per in. Arc current gain is a function of the furnace transformer voltage, the resistance and reactance of the bus bars and transformer, as well as the arc itself.

Analytical and measured response

To determine the accuracy of such an analysis, an existing system was analyzed, and results were compared to tests made on a control system. The system was electrohydraulic, the electrode mast being directly positioned by a hydraulic cylinder. Movement of the cylinder rod was controlled by an electrohydraulic controller which received signals of both arc voltage and arc current.

The electrohydraulic controller is based on the jet pipe principle, shown in Fig. 6. A hollow rod about 8 in. in length is pivoted at one end. Hydraulic pressure is applied at the pivoted end, causing a stream of fluid to emerge from the free swinging end. The stream of fluid impinges on a flat plate in which two holes are drilled. When the stream is directed between the two holes, the pressure recovered in each is identical, but displacement of the rod causes the pressure recovered in one orifice to increase and the other to decrease. The orifices are connected to a hydraulic cylinder and the hydraulic pressure is employed to move the cylinder rod.

Fig. 7 shows the moving coil element which is used to move the jet pipe. This element consists of a coil of wire placed in a magnetic field; when voltage is applied to the coil, a force is produced which moves the jet pipe. Since the jet pipe is spring restrained, its displacement is directly proportional to applied voltage. For arc furnace applications two coils are used: one for arc current and the other for arc voltage.

The operation of the system depends on the balance of arc current and arc voltage. When the proper balance exists, the jet pipe is centered and the cylinder is stationary. An unbalance causes the jet pipe to be displaced. Hydraulic fluid flows to the cylinder, causing movement of the rod and consequent movement of the electrode until a balanced condition is again achieved.

In making the analysis, the gain and dynamic characteristic of each component in the system was determined. It was then necessary to determine the voltage and current gain of the arc. Since accurate knowledge of the power circuit impedance was not available, this was determined by measurement on the system.

A potentiometer was connected to the electrode mast to provide a voltage proportional to electrode position, the voltage being applied to the horizontal plates of an oscilloscope. The arc voltage was applied to the vertical plates of the oscilloscope. As

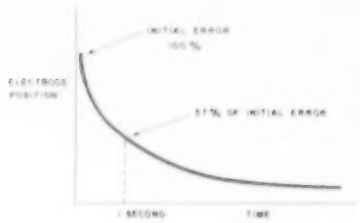


Fig. 9—Electrode position vs time, showing rapid recovery.

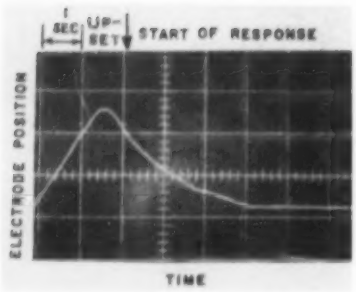


Fig. 10—Step function response of arc furnace control. Horizontal rules indicate ½ in.

the arc length changed, the trace moved across the screen, producing a picture as shown in Fig. 8. The height of the trace increased with arc voltage. The slope of this picture is change of arc voltage per change in arc length. In this case the measurement was 12 v per in.

The arc current gain was measured in the same way, except that the arc current signal was applied to the vertical plates of the oscilloscope. The arc current versus arc length trace showed an average slope of about 160 amps per in.

The theoretical analysis was made to determine the response of the electrode after an instantaneous error in arc length. This could be caused by a rapid movement of the furnace charge. The result of the analysis showed the predicted response of Fig. 9. After 1 sec the electrode has corrected to within 37 pct of the original error.

In testing the actual system, an electrical signal is obtained which is proportional to the position of the electrode. This signal is applied to the vertical plate of an oscilloscope. The horizontal movement on the oscilloscope is a function of time. Fig. 10 is a photograph of the response obtained. The electrode was initially displaced to a certain point, and the controller was then allowed to operate. The electrode reached 37 pct of the initial error in about 1.3 sec. This is to be compared with the 1 sec value obtained in the analysis.

The accuracy in this case is about 30 pct. Considering the initial approximation and the great changes in the furnace itself, this is reasonable accuracy. As stated before, the analysis is sufficient to give a good indication of furnace performance, although not an exact indication.

It was found in the analysis that by increasing the gain of the controller, that is the jet pipe, the system could be made highly oscillatory. This is accomplished by putting lighter springs in the controller. This increase in gain made the system operate more rapidly, but also produced considerable fluctuation during normal operating conditions. After the initial error, the correction was made quite rapidly, but afterward the electrode is quite oscillatory in attempting to follow the rapid fluctuations in the electric arc. The analysis thus showed how the system was to be designed in order to avoid this condition.

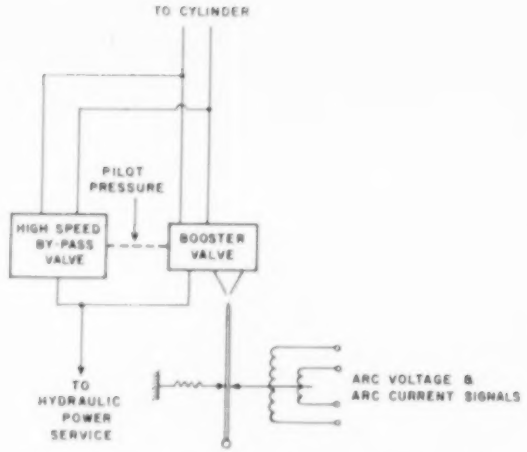


Fig. 11—Control system using a bypass valve which quickly corrects for large upsets in the furnace.

Use of the analysis

An analysis was used to determine the feasibility of modifying the system previously described so that normal regulation would employ relatively slow electrode speeds, but that high speeds would be available for large upsets. The system of Fig. 11 was proposed. Normal control is the same as before. Under conditions of large upset within the furnace, the jet pipe and booster are driven to the limits of travel. Hydraulic interconnection opens a four-way valve which by-passes the booster valve and allows a large quantity of fluid to flow. The question which arose was whether the stability of the system would be affected by the by-pass valve.

An analysis of the system showed that the system was feasible. The system was later built and corroborated the theoretical conclusions. Normal regulating speed was 6 ft per min; the over-ride speed was 22 ft per min. No difficulty with stability or electrode breakage was encountered.

Conclusion

The example cited shows that a reasonable correlation can be achieved between the theoretical and actual operation of an electrode control system. A mathematical simulation of the control system is, therefore, possible. This simulation can be used for choosing components, predicting adjustments, and for making modifications to the system.

The limitations of the analysis must be appreciated. Each approximation makes the analysis less accurate. In many cases it is necessary to consider such factors as gear backlash, friction, saturation phenomena, and so on in order to obtain a reasonable degree of accuracy. In no case should it be expected that an exact duplication of the physical system will be obtained, but this is usually not necessary.

Further investigation into the analysis of such systems will undoubtedly be made. While the more practical aspects must always be considered, mathematical study will continue to aid our understanding of the system. In this way, the theoretical and practical knowledge can be combined to achieve continual advancement in electric arc furnace control.

Paper presented at AIME Annual Meeting, February 1957

by James C. O. Harris

Raw Materials For the American Iron and Steel Industry

During the past several years there has been much discussion about future requirements of iron and steel. Of equal concern are the quantities of raw materials that will be needed and their sources. To supply this rapidly expanding industry for the next 20 years, we may need almost twice as much iron ore and metallurgical coke as during the past score of years.

AT the beginning of 1957 the Nation's steelmaking capacity was 133 million net tons, a 46 pct increase during the past 10 years. Predictions by a number of steel executives are that by 1960 capacity will be between 140 and 145 million net tons and by 1975 between 180 and 200 million tons.

Steel consumption

Consumption of steel per capita 10 years ago was 1190 lb, based on ingot output, compared with the estimated 1957 rate of 1415 lb. This is an equivalent annual increase of about 2 pct per capita. If U.S. population increased at the same rate to 1975 that it has during the past 10 years and with a per capita consumption increase of only 1 pct a year, then U.S. ingot requirements are estimated at 180 million tons in 1975.

Pig iron requirements

To supply an industry of this size, pig iron requirements in 1975 will be 130 million tons compared with 77 million tons in 1955. The increased requirements for pig iron and scrap are given at five-year intervals in Table I and Fig. 1. The requirements listed in this table and other tables in this paper are based on past production and consumption data published by the American Iron and Steel Institute (AISI), Bureau of Census, and U. S. Bureau of Mines (USBM). For the purpose of this table, an average operating rate of 90 pct of capacity for the iron and steel industry has been assumed. Calculated requirements for pig iron and scrap in Table I are estimated using different ratios. The figures under A are estimated on the assumption that the pig iron-to-scrap ratio for ingot producers remains unchanged from present practice through 1975 and will consist of 52 pct pig iron and 48 pct scrap. The figures under B are derived by assuming that the pig iron-to-scrap ratio changes from the above 52:48 ratio to a 60:40 ratio by 1975.

In calculating these requirements for pig iron and scrap, certain further assumptions or estimates were made. These are: 1) that the output of hot-melt open-hearth furnaces will decrease from their present 83 pct of total steel output to 81 pct by 1975; 2) that production from cold-melt open-hearth and bessemer furnaces will remain constant at 11 million tons, electric furnaces will maintain their position at 7 to 8 pct of total output, and oxygen steel will gradually increase to 10 million tons by 1975; and 3) that the annual consumption of independent foundries would increase to 22.5 pct by 1975 and that the foundry charge would consist of the present mix of 70 pct scrap and 30 pct pig iron.

Iron ore supplies

To meet the high demand for pig iron in the coming years, an increase of 40 to 60 pct in iron-ore requirements may be expected; undoubtedly most of this will come from foreign sources. U.S. iron ore imports in 1956 were 30.4 million tons, compared with 2.8 million tons 10 years ago. The requirements and probable sources of iron ore are given in Table II. In computing the iron ore required for blast furnaces, it was estimated that the iron content of the blast furnace feed (ore and sinter) would increase from the estimated 53 pct for 1957 to 58 pct by 1975.

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Table I. Estimated Steel Demand and Pig Iron and Scrap Requirements in the U. S., 1957 to 1975 (million net tons)

Year	Steel Ingots[1]		Metallics for Steel Plants				Metallics for Independent Foundries and Other Uses[2]		Total Requirements			
			A		B				A		B	
	Capacity	Production	Pig Iron (52 pct)	Scrap (48 pct)	Pig Iron (52–60 pct)	Scrap (48–40 pct)	Pig Iron	Scrap	Pig Iron	Scrap	Pig Iron	Scrap
1957	133	120	72.5	66.5	72.5	66.5	7.0	17.0	79.5	83.5	79.5	83.5
1960	145	130	78.5	72.0	81.5	69.0	7.5	17.5	86.0	89.5	89.0	86.5
1965	160	144	87.0	80.0	93.5	73.5	8.0	18.5	95.0	98.5	101.5	92.0
1970	180	162	98.0	90.0	109.0	79.0	8.5	19.5	106.5	109.5	117.5	98.5
1975	200	180	108.5	100.0	125.0	83.5	9.0	20.5	117.5	120.5	134.0	104.0

[1] Based on projected population increases and a 1 pct per annum increase in per capita consumption.
[2] Assuming 5 pct increase each three or five years.
[3] No change.
[4] Assuming 2 pct change for each three or five years.

Table II. U. S. Iron Ore: Estimated Requirements and Sources, 1957 to 1975 (million gross tons)

Year	Category[1]	Ore Requirements			Sources			
		Blast Furnaces[2]	Steel Furnaces	Total Required[3]	U. S.	Canada	Latin America[4]	Other
1957	A	117.4	8.6	126	95	15	14	2
	B	117.4	8.6	126	95	15	14	2
1960	A	125.7	9.3	135	94	20	18	3
	B	130.0	10.0	140	94	24	19	3
1965	A	135.5	10.5	146	92	28	23	3
	B	144.7	11.3	156	92	37	24	3
1970	A	148.5	11.5	160	95	34	27	4
	B	164.0	14.0	178	97	44	32	5
1975	A	160.1	12.9	173	100	38	31	4
	B	183.2	18.8	202	110	46	40	6

[1] See table I. (B)—Assuming that the percentage of output of hot-metal open hearths decreases from its present 83 pct of total steel output to 81 pct by 1975 and also assuming that cold-melt open hearths, plus bessemer steel, remain constant at 11 million tons, electric furnaces maintain their position at 7 to 8 pct of total output, and oxygen steel gradually increases to 10 million tons by 1975; also assuming that the metallic charge of hot-metal open hearths will change from the present 60 pct pig iron and 40 pct scrap to 66 pct pig iron and 34 pct scrap by 1975.
[2] Assuming 5-pct increase in Fe content.
[3] Includes iron-ore equivalent of sinter required.
[4] Includes Mexico.

Table III. Estimated Coke and Coal Requirements of the American Steel Industry (million net tons)

Year	Pig Iron Production		Coke Requirements Per Ton Pig Iron	Total Coke Requirements		Total Coal Requirements[1]	
	A	B		A	B	A	B
1957	79.5	79.5	0.850	67.6	67.6	96.7	96.7
1960	86.0	89.0	0.836	71.9	74.4	102.9	106.4
1965	95.0	101.5	0.812	77.1	82.4	110.3	117.9
1970	106.5	117.5	0.790	84.1	92.8	120.3	132.8
1975	117.5	134.0	0.765	89.9	102.5	128.6	146.6

[1] On the basis of yield of coke (exclusive of breeze) of 69.9 pct the approximate average over the past 20 years.

Table IV. Estimated U. S. Scrap Supply (million net tons)

Year	Ingot Producers (Category A)		Ingot Producers (Category B)		Independent Foundries	
	Home	Purchased	Home	Purchased	Home	Purchased
1957	38.5	28.0	38.5	28.0	8.0	9.0
1960	41.5	30.5	41.5	27.5	8.5	9.0
1965	46.0	34.0	46.0	27.5	9.0	9.5
1970	52.0	38.0	52.0	27.0	9.5	10.0
1975	57.5	42.5	57.5	26.0	10.0	10.5

Table V. Estimated U. S. Purchased Scrap Supply, Including Foundries (million net tons)

Year	Category A			Category B		
	Prompt Industrial Scrap	Obsolete Scrap	Total Purchased	Prompt Industrial Scrap	Obsolete Scrap	Total Purchased
1957	12.0	25.0	37.0	12.0	25.0	37.0
1960	13.5	26.0	39.5	13.5	23.0	36.5
1965	14.5	29.0	43.5	14.5	22.5	37.0
1970	16.5	31.5	48.0	16.5	20.5	37.0
1975	18.0	35.0	53.0	18.0	18.5	36.5

For steel furnaces it was assumed that there would be no change in the average iron content of iron ore used and that, for category A, the pounds of ore per ton of steel would remain at 161 lb.

In computing the iron ore requirements for category B, it is assumed that the blast furnace feed will be the same as for category A. However, for the steel furnaces it is estimated that the ingot output for hot-metal open hearths would increase from 100 million tons in 1957 to 146 million tons in 1975. With the pig iron portion of the charge increasing from 60 pct to 66 pct during these years, it is esti-

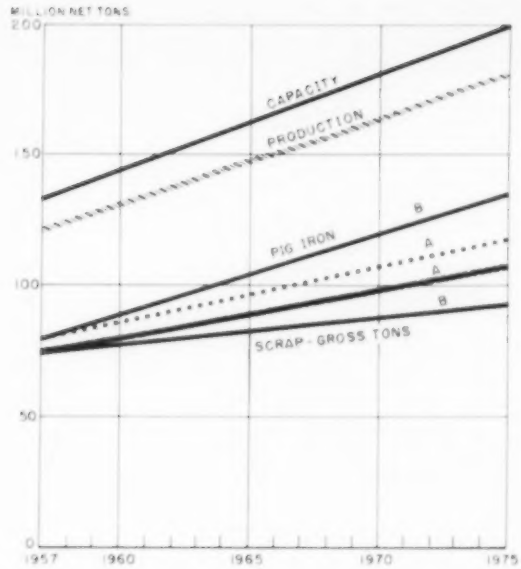

Fig. 1—Estimated steel capacity and production together with pig iron and scrap requirements. "A" assumes unchanged pig iron-to-scrap ratio, while "B" assumes ratio increases from 52:48 to 60:40.

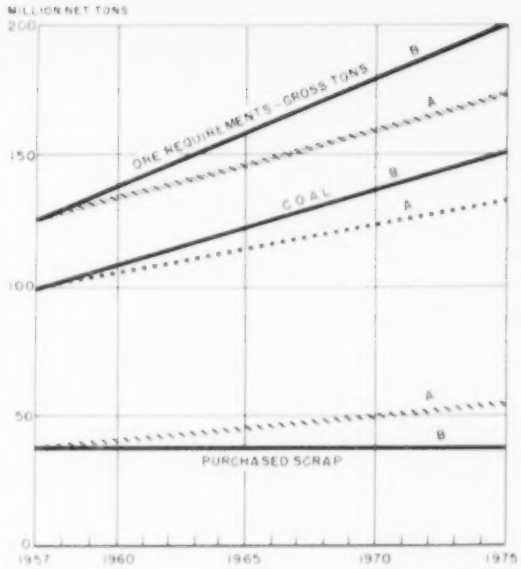

Fig. 2—Estimated ore, coal, and purchased scrap requirements of the American steel industry.

mated that the iron ore and sinter portion (charge and feed) would increase from the present 8.6 pct of the metallic charge to 12.6 pct by 1975. Mill cinder and scale required were not included in the figures.

Beneficiated ore

In augmenting the supply of direct-shipping ores from the Mesabi, we must look to beneficiated low-grade iron ores from the Lake Superior region and ores from Canada and South America. Canadian supplies will include direct-shipping ores from Knob Lake and Steep Rock deposits and beneficiated ore from Marmora and Michipicoten deposits. Other developments in Canada are the extensive iron ore project of U. S. Steel Corp., which will include a concentrating plant at Mt. Wright and a private railroad to Shelter Bay where dock facilities will be built, a large deposit in Labrador under development by Canadian Javelin Ltd., and the Iron Ore Co. of Canada which is planning significant exploration in the Wabush Lake area. Increased tonnages are expected from Venezuela and Chile. Peru and Brazil will, no doubt, be upping their shipments to the U.S.

In the U.S., 40 million tons of agglomerates from the Minnesota taconites and the Michigan jaspers may be expected within the next 10 years. Sintering capacity is also increasing, and by the end of 1957 it will have increased to 63 million tons from 38 million tons in 1955. Other developments in beneficiation are underway in iron ore districts in a number of states.

Coke requirements

Coke and coal requirements for categories A and B are given in Table III. In computing the coke requirements, it is estimated that the coke required per ton of pig iron would be reduced 10 pct by 1975. During the past 20 years the average national yield for coal to coke has been 69.9 pct. This figure was used in computing future requirements.

Of the 106.6 million net tons of coking coal delivered to oven plants in 1955, 65.6 pct was high-volatile, 10.8 pct was medium and 23.6 pct was low-volatile. USBM records show that there is an ample supply of high- and medium-volatile coal for the next 100 to 200 years; however, the remaining known reserves of low-volatile coal that constitute less than 1 pct of total reserves of all ranks are estimated at nearly 17 billion tons, as of Jan. 1, 1953. Of this tonnage, it is estimated that only 4 billion tons is recoverable by modern mining methods. In 1955, 30 pct of the 83 million net tons of low-volatile coal produced was delivered to coke plants. If a shortage should develop in the supply of low-volatile coal, char or semicoke made by partial carbonization of high-volatile coal could be used as a substitute.

Scrap needs

A forecast of the requirements for scrap for the iron and steel industry through 1975 is presented in Tables IV and V. A home-scrap factor of 32 pct for ingot producers, based on the past five-year average ratio of home scrap produced to ingot output, was used in computing future home scrap for this group. The data given for independent foundries and other uses are based on previous consumption data by these industries, with an estimated 22.5 pct increase in consumption by 1975. Total purchased scrap for all industries is summarized under categories A and B. It is noted that the purchased scrap requirements for category B remain almost constant because of the predicted changes in pig iron-to-scrap ratio for this category.

A 12-pct factor was used for prompt industrial scrap. This is based on the USBM Materials Survey

on iron and steel scrap and an estimated 1 pct increase in prompt scrap generation. The 12-pct factor, used in the Survey, for steel-mill products is based largely on an actual survey of the flow of finished rolled-steel products made by a committee of the AISI in 1947. Estimates of 3 to 5 pct for foundry prompt industrial scrap are given in the USBM Survey. On combining and recomputing the above factors, a new factor of 11 pct was developed for all shipments of iron and steel products. Since the market for lighter steel products has increased over the years, which results in more prompt industrial scrap, a 12-pct generation factor has been used in this paper.

Since the above table was prepared, the Battelle Memorial Institute has published its survey on iron and steel scrap, which includes a factor of 15.7 pct for future years. It was developed on somewhat the same basis as the USBM Survey. This factor was estimated in large part on the basis of preliminary results of a survey of 2328 plants conducted by the Bureau of the Census.

As shown in Table V, according to the earlier USBM estimates, 33 pct of future purchased scrap could be supplied as prompt industrial scrap for categories A and B, using a factor of 12 pct. If the Battelle Memorial Institute's factor of 15.7 pct is used, the annual generation of prompt industrial scrap increases by some 4 to 6 million tons, the obsolete requirements being reduced by the same quantity. The requirements for iron ore, coal, and purchased scrap from Tables II, III, and V are summarized in Fig. 2.

Effects of new steelmaking techniques

Western Europe and Japan are increasing their ratio of pig iron to scrap; moreover, Japan is installing oxygen converters. At least five steel companies in the U. S. are installing or have installed oxygen converters. Other processes that would increase requirements for pig iron are the use of desiliconized hot metal and the oxygen jet process for open hearths. New developments in the use of scrap are the metallurgical blast cupola, which is capable of making molten pig iron for open hearth use from a 100 pct scrap charge, and the use of a portable gas-fired scrap preheater developed by the USBM to preheat scrap for electric furnaces. The latter innovation greatly reduces the energy cost and heat time for electric-furnace steelmaking.

A process that would greatly reduce the supply of home scrap is continuous casting. This process is currently being used in the U.S. and Canada.

Scrap substitutes

When the price of scrap increases, the iron and steel industry becomes interested in possible substitutes for scrap. Sponge iron has been used in Sweden and Mexico as a substitute for scrap for a great number of years. In 1947 the USBM, in cooperation with industry, utilized a high percentage of sponge iron as a melting stock in tests at industrial open hearths and electric furnaces. A new type of sponge iron, called H-Iron, has recently been developed by Hydrocarbon Research Corp.; it may also be used as a steel-furnace melting stock. A recent despatch from Germany states that West Germany is installing six rotating-drum furnaces with an annual capacity of almost 400,000 tons for the production of iron pellets to reduce the country's deficit of scrap.

Other factors in scrap supply

Factors other than availability also govern the use of scrap; these include density, contamination, and metallic recovery. In 1951 Kaiser Steel Corp. increased its production rate substantially by increasing the open hearth charging-box density through better scrap preparation. The problem of contaminants and residual elements in steel has been discussed by Herty, Williams, Sullivan, and Pavlish; also a survey was conducted by the AISI in 1947.

The recovery of metallics in steelmaking varies with the type of charge used and is a significant factor in the overall economy of any given practice. The total loss runs from about 6 to 16 pct, depending on the type of charge, the degree of oxidation from the flame in open hearths, slag volume, slag basicity, and tapping carbon, as well as upon whether or not a runoff slag is involved. The ideal condition for high recoveries is to maintain the oxygen level as low as possible, consistent with maximum production and good quality. The usual furnace charge is composed of a balanced mixture of heavy and light scrap; however, to determine actual recoveries by grades, a number of experimental heats of steel have been made from one grade of scrap. With all Heavy Melting scrap, a yield of over 90 pct would be expected. If all purchased No. 2 bundles were used, the yield usually would be somewhat lower. In one experiment conducted in this country, the metallic recovery from rusted tin can scrap was only 60 pct. The scrap and steel industries are currently studying methods to improve the quality of bundles. The U.S. practice has been to use a metallic charge with a scrap portion of approximately 40 pct Heavy Melting scrap and 26 pct bundle scrap. On the other hand, of the 11 million tons of scrap exported from the U.S. during the past two years, 60 pct has been the Heavy Melting grades, and only 13 pct has been bundles. Although the exportation of these grades may sound out of proportion, there has been no significant change in the stocks of the grades at consumers' plants during the past five years.

Summary

Recapitulating the total estimated raw material requirements for the American iron and steel industry for 1957 to 1975:

	Million tons		
	1957	1975	
Iron ore	2,765	3,125	(gross)
Coal	2,160	2,340	(net)
Purchased scrap	700	855	(net)

The magnitude of these requirements is so enormous that they command our most intensive efforts in conservation through development of efficient utilization practices.

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by F. W. Luerssen,
J. W. Halley,
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AN OXYGEN STEELMAKING PROCESS

High carbon, low phosphorus steel can now be made from pig iron containing 0.7 pct P or more, in a commercial sized open hearth furnace. No external heat is required for refining, and steel produced is identical with basic open hearth steel.

THE classical Thomas process, which requires liquid pig iron containing over 1½ pct P, yields a product relatively high in phosphorus and nitrogen. Unless large quantities of recarburizers are added to the refined steel, the product is low in carbon content. Thus, the Thomas process is not well suited to American raw materials, and its product is often not acceptable according to the standards set by American industry.

The shortcomings of the Thomas process have long been recognized; with the advent of low cost oxygen, studies were initiated to develop pneumatic processes which would conceivably overcome the inherent objections to Thomas steelmaking. Several such modified basic pneumatic processes have been tested experimentally in commercial trials during the past decade. Probably the most widely publicized of these developments has been the oxygen converter process as practiced in Austria[1,2] and in Canada.[3] In this process, oxygen is substituted for air and introduced above the liquid bath in order to increase the heat available to the metallurgical system. This avoids the need for high phosphorus raw materials and gives a product low in nitrogen. In this process, the phosphorus content in the final product depends, to a considerable extent, on the total amount of that element in the burden.

The rotary furnace[4] which is now in commercial operation at Domnarvet Steelworks, Sweden, is producing low phosphorus steel from iron containing 1.8 to 2 pct P. One or more early slags are removed and by this means high carbon steels of open hearth quality can be produced. At this stage of development there is some question as to the applicability of the rotary process to large heats.

Another development has been the use of oxygen in combination with either steam[5] or carbon dioxide[6] in the basic bessemer, thus avoiding the introduction of nitrogen gas into the refining system and giving a product relatively low in nitrogen content. A double slag process has been used in Europe[7] in conjunction with a regular Thomas converter, by means of which it is possible to obtain a phosphorus content in the product approaching that obtained in basic open hearth steels. The Turbo-Hearth process,[8,9] which uses the side blowing principle so as to produce low nitrogen steel from normal American pig irons, has been developed experimentally in this country.

A process fitted to U. S. raw materials

All of the preceding processes, with the exception of the rotary furnace, suffer from the common shortcoming that they cannot be adapted to the production of high-carbon, low-phosphorus steels unless large proportions of recarburizers are added. In 1947, a program was initiated by the Inland Steel Company[10] to study an oxygen steelmaking process specifically designed to utilize the full range of phosphorus analyses encountered in American pig irons and to give final products with phosphorus and nitrogen contents comparable to steel produced by the basic open hearth process. Some of the objectives of the proposed process are: 1) the process should be able to accommodate molten pig iron containing up to 1 pct P., 2) the process should be subject to close control of carbon analysis, 3) the process should be capable of producing high carbon

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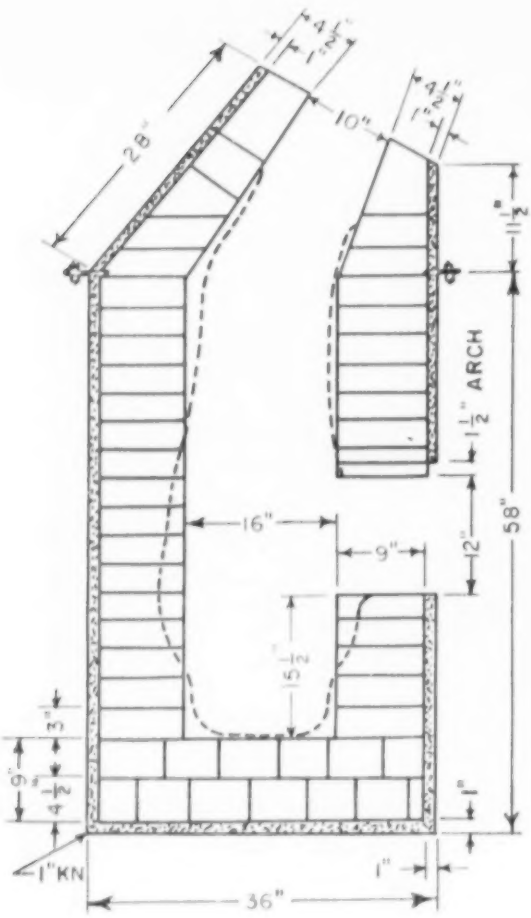

Fig. 1—Left: Cross section of the basic lined furnace used in the 750 lb tests. The tuyere box and wind pipes were removed from the original, and a port was cut in the side to observe lancing.

Fig. 2—Above: The 750 lb converter, showing the general construction and gearing arrangement, which allowed a 90° tilt in either direction.

steels without the use of large proportions of recarburizers, 4) the product should be low in nitrogen content (under 0.004 pct, 5) the phosphorus content in the product should be comparable to that obtained by the basic open hearth process for the same type of steel and the same carbon content, 6) during refining, phosphorus should reach low levels before the carbon content approaches the range desired in the final product, and 7) under normal conditions, the process should require no external heat for refining.

Some cursory studies made in 1948 demonstrated that with careful control of the charge materials and with regulated practices for introducing oxygen in the steelmaking system, a sequence of metallurgical reactions was attained that fulfilled the preceding requirements. Following this exploratory work, a series of 61 test heats were conducted in a modified side blown converter of about 750 lb capacity. These studies gave some insight into the metallurgical aspects of the proposed oxygen steelmaking process and served as a basis for planning large-scale experiments. The large-scale experiments consisted of four 125 ton heats made in an open hearth furnace that was modified to accommodate large volumes of lance oxygen for refining without the use of any external fuel.

The results obtained in these studies are presented in two separate sections of this paper. The first section describes the experiments conducted in the modified side-blown converter. The second section, which covers the results of the 125 ton tests, is intended to show the similarity of the pattern of refining reactions in the steel for two heat sizes.

Tests in 800 lb converter

Equipment: The sketch shown in Fig. 1 indicates the general proportions of the reaction vessel used in carrying out the 750 lb heat tests. The vessel was originally designed as a 1000 lb capacity side-blown acid converter. For the purpose of these studies, the tuyere box and wind pipes were removed from the original 36 in. diam shell. An 11 in. square opening was cut into the outer shell to serve as a port through which lancing could be observed. A refractory lined door was made available to cover this lancing port when the vessel was not being operated.

The initial working lining was built up of regular 9 in. low-iron basic brick. This lining was separated from the shell on all sides by a 1 in. layer of plastic chrome refractory. This heavy lining enclosed a 16 in. diam by 15-½ in. deep reaction chamber.

The vessel, which was mounted in side trunnions, could be tilted more than 90° from the vertical in both directions through a gear arrangement. A photograph of the outer shell, showing the lancing port and the general construction, is shown in Fig. 2.

The vessel was pre-heated by means of an air-gas burner. This same facility was used between heats to avoid excessive temperature drop in the basic refractory.

Table I. Approximate Analysis of Pig Iron, Sinter Ore and Limestone, Pct

	C	Fe	Mn	Si	P	S	SiO_2	CaO	Al_2O_3	MgO	R_2O_3	Ign. Loss
Pig Iron	4.00		1.50	1.00	0.24	0.035						
Sinter Ore		65	0.4		0.27	0.02	4.0		2.0			
Limestone							0.7	52		2.3	0.9	44

Standard ¼ in. pipe was used for lancing throughout this test. For the most part, the only refining gas used for the process was oxygen. While the simple lance construction provided an effective method of introducing oxygen into liquid metal, periodic short delay periods were frequently required to replace the pipe or readjust it to obtain samples and to make furnace additions. High purity oxygen was supplied from a ten-tank manifold. With this arrangement the oxygen pressure at the furnace was 55 psig.

The only severe refractory lining erosion that was encountered during the study occurred on the back wall directly opposite the lance position. At this position, it was necessary to patch the refractory after each 8 to 10 heats. A normal mixture of high magnesia patching refractory and open hearth slag was found satisfactory for this repair operation. The dotted line of Fig. 1 shows the extent of refractory erosion and build up after 61 heats.

Typical operating practice

Hot metal was supplied from an induction furnace. Molten metal of known analysis and controlled temperature was tapped into a lip-pour-ladle and transferred to the experimental steelmaking furnace by a 5-ton overhead crane. The experimental furnace was maintained at a temperature of 1900°F during non-operating periods by firing with the available domestic gas.

The normal charge materials were limestone, sintered iron ore, basic pig iron and steel scrap. The limestone was specifically sized for experimental work and averaged about 2 in. diam. The sinter ore varied from fines to 2 in. in size. Selected 2 in. square by ½ in. thick pieces of plate scrap were used for covering the ore charge. Approximate analyses of the pig iron, sinter ore, and limestone are given in Table I.

Limestone, sinter ore and scrap were charged in the sequence indicated to the preheated furnace. Except where the quantities of these materials were varied for special studies, the following standard charge was used: a.) limestone (6 pct of hot metal weight), b.) sinter ore (6 pct of hot metal weight), and c.) scrap (25 lb).

Upon addition of these solid materials, the furnace was tilted about 45° and approximately 100 lb of liquid iron was added. After 30 sec, the remaining 650 lb of molten metal was charged and the furnace was returned to a vertical position. The oxygen lance was then inserted into the bath which, by this time, was boiling actively. During the first few minutes of lancing, a hot liquid slag formed. Although it was not always possible, it was aimed to retain the first slag in the furnace for a total time of 10 min before flushing. During formation of the flush slag, samples of metal and slag were taken at intervals of from 1 to 3 min. Flushing generally started when 8 to 10 in. of foamy slag covered the metal surface. By tilting the furnace forward, with the exit end of the oxygen lance located near the slag-metal interface, a foaming slag condition was developed which permitted removal of almost all of the slag through the side opening.

After the flush, lancing was briefly interrupted while controlled quantities of burnt lime and fluorspar were added. At 5 min intervals, additional amounts of burnt lime were charged as required. The quantity of fed burnt lime varied from 3 to 5 pct of the charge depending on the amount of sulfur or phosphorus in the charge. To avoid excessive foaming and also to aid in lime solution, additional small quantities of spar were used.

For the first 20 min following hot metal addition, test slugs for chemical analysis were obtained by inserting a graphite rod with two cavities drilled near its lower end into the bath. The slag adhering to the graphite rod after withdrawal was used as the corresponding slag sample. After the initial 20 min period and until the carbon was reduced to the desired level, standard carbometer tests were utilized.

Due to excessive foaming of working slags, intermittent flushing was sometimes necessary. This flushing action could be partially controlled by tilting the experimental furnace and by adding burnt lime. Thus, to maintain a sufficient slag volume, it was sometimes necessary to use an excess of lime.

After the desired carbon content and bath temperature were attained, the furnace was tilted forward and the metal, along with considerable slag, was poured into a teapot ladle preheated to 1100°F. Additions of ferromanganese and aluminum were made during this period. The final steel was then poured into specially constructed big-end-up, split hot topped molds. The teapot ladle was not a satisfactory pouring arrangement since slag trapped in the spout was poured along with the molten steel into the molds. As a result, considerable slag was often entrapped within the solidified ingot.

Discussion of results

Such a large volume of data was taken in studying the chemistry of the 750 lb heats that it is impossible to show detailed data on all heats. However, the general characteristics of the heats were very similar. Typical heat logs are presented to show the general trends.

The first several heats were made while experience was being gained in the control of the process and in the manipulation of the equipment. The log of a typical heat made during the latter portion of this period, shown in Fig. 3, demonstrates the general behavior of the process quite clearly. The fairly uniform rate of carbon drop is the result of a nearly constant oxygen blowing rate. The rapid elimination of phosphorus in a highly oxidizing flush slag early in the refining is the distinguishing characteristic of the process, which makes possible the production of high carbon, low phosphorus steel.

In general, the flush slag was removed from 5 to 10 min after the start of blowing. The removal of slag with only a few exceptions did not result in discontinuities in the phosphorus drop. However, occasionally the slag was completely removed. This left the bare metal exposed to the atmosphere and,

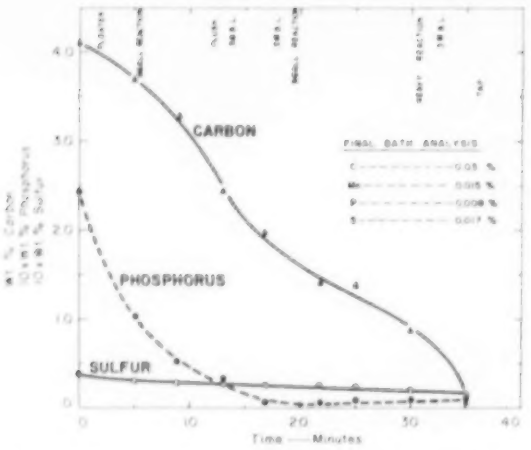

Fig. 3—The course of refining heat no. 22 in the 750 lb furnace.

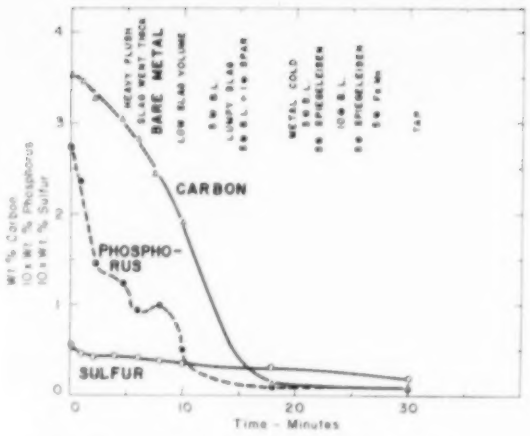

Fig. 4—The course of refining a heat where the slag cover was removed and phosphorus refining was interrupted.

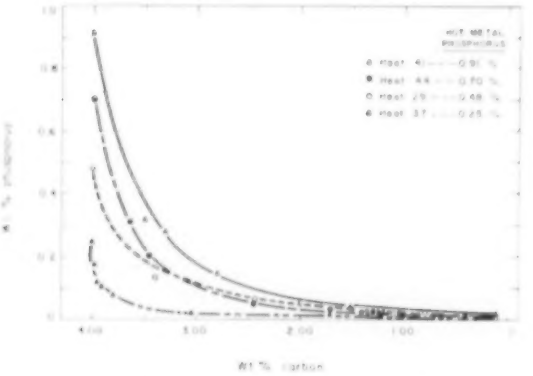

Fig. 5—Relationship between carbon and phosphorus in refining low to high phosphorus heats.

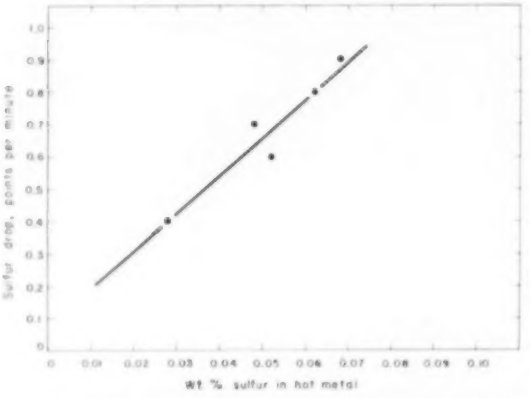

Fig. 6—Effect of sulfur on the rate of sulfur removal; hot metal at 1.4 pct Mn and 2500°F.

as would be expected, the phosphorus elimination was arrested until slag-making additions were fed to the furnace. Fig. 4 shows this effect of complete slag removal in arresting dephosphorization and the effect of burnt lime additions to the bare metal in re-establishing the normal phosphorus drop.

The process has an unusual ability to remove phosphorus

This was investigated by making a series of heats from hot metal containing about 0.25 pct P to about 0.9 pct P. Fig. 5 is a plot of phosphorus concentration as a function of carbon concentration in four heats selected from the series. This presentation was chosen to eliminate effects of changes in the oxygen blowing rate. In the two heats with high initial phosphorus, the fed lime was increased from the normal 25 lb to 35 lb. Fig. 5 demonstrates that the phosphorus concentration curves are strongly convergent as carbon is eliminated and that low levels of phosphorus can be attained at high carbon concentrations.

Table II is further demonstration of the ability of the process to remove phosphorus. It shows, from a mass of averaged data, the rapid early elimination of phosphorus as well as the low phosphorus concentrations obtained during refining for a wide range of initial phosphorus concentrations. These data demonstrate that hot metal containing up to 0.7 pct P can be converted to low phosphorus steel and that it is probably possible to produce low phosphorus steel from hot metal containing as much as 1 pct P with appropriate attention to the flush and refining periods of the process.

Sulfur removal

Another feature of the process is worthy of discussion; namely, its ability to remove sulfur. This was investigated on a number of heats in which the sulfur content of the hot metal was varied widely. Average data from these heats are listed in Table III.

The data of Table III demonstrate that more sulfur is eliminated as the sulfur burden is increased. Between 53 and 64 pct of the initial sulfur burden was removed during refining. A further demonstration of sulfur elimination in the process is contained in Fig. 6 which is a plot of the effect of initial sulfur levels on the average rate of sulfur elimination. A marked and well defined increase is seen in the rate of sulfur drop as the initial sulfur concentration is increased.

A sharp initial drop in sulfur was observed on many heats. This occurred between hot metal ad-

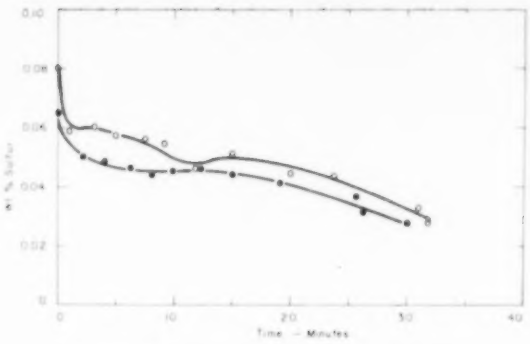

Fig. 7—Early sulfur elimination in two 750 lb heats.

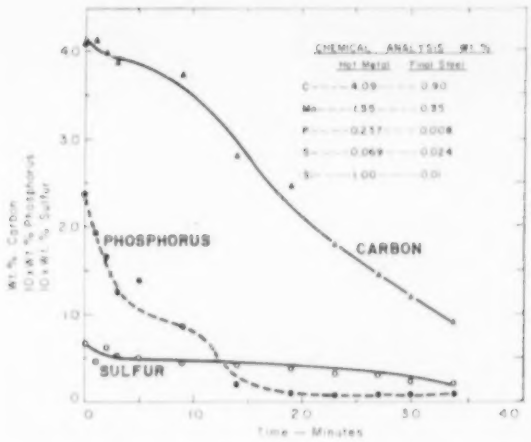

Fig. 8—Course of refining heat no. 38, a high carbon heat.

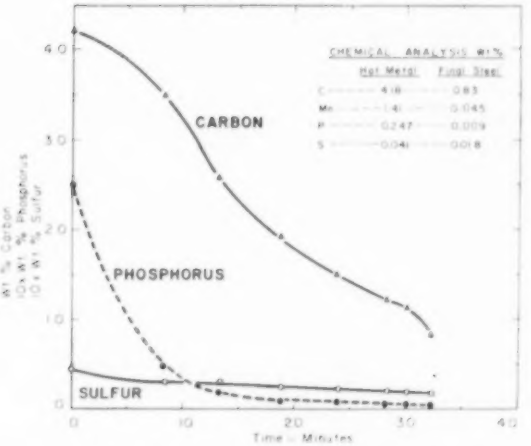

Fig. 9—Course of refining heat no. 40, also a high carbon heat.

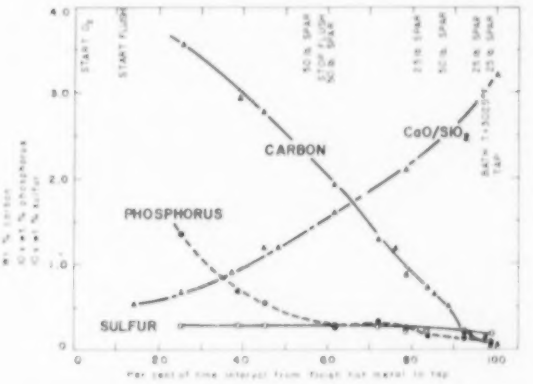

Fig. 10—Course of refining 125 ton heat no. 4, also showing the CaO/SiO_2 ratio.

dition and the earliest sample that could be taken. Two examples of rapid early sulfur elimination are shown in Fig. 7. This observed phenomenon remains unexplained since the cause has not been and perhaps cannot be separated from the data.

As experience was gained with the process it became possible to tap the heats at any desired carbon level. This is demonstrated in Fig. 8 and Fig. 9 which are the logs of two high carbon heats. It is both interesting and important to observe that, despite the high final carbon content, the phosphorus had already been eliminated down to a desirable level. These two heats show that hot metal containing up to 0.250 pct P can be converted to high carbon (0.8 pct C) steel containing as low as 0.010 pct P.

Aside from the qualities of the process to produce low phosphorus and low sulfur steel it also possesses the features necessary to the production of low nitrogen steel. Nitrogen analyses of bath samples from all 61 heats and from the ingots of seven heats ranged from a trace to 0.003 pct nitrogen. This was not unexpected since very high purity oxygen (99.5 pct O_2) was used experimentally.

Commercial size heats—125 tons

Results of experiments in the 750 lb basic lined vessel show that the process is capable of producing high and low carbon steels which are low in phosphorus, low in sulfur and low in nitrogen, from hot metal containing up to 0.7 pct P and 0.07 pct S, without recarburization and without external firing. These results fulfilled the objectives of the original program. Because of these very encouraging results an experimental program was proposed for carrying out the process on a commercial scale. The studies to this time had indicated that a departure from a converter shaped vessel to a hearth type furnace might be beneficial to the process. After considering several approaches it was decided to modify an existing open hearth furnace to permit the same sequence of operations as has been described for the 750 lb heats.

The commercial size experiments were conducted in Inland's No. 2 Open Hearth shop when shop conditions existed such that experimental work would not seriously interfere with operations. Four heats were made in a modified 175 ton open hearth fur-

Table II. Effect of Initial Phosphorus Concentration on Phosphorus Concentration in the Steel during Refining

No. of Heats	Avg P in Hot Metal, Wt Pct	Avg P After Flush, Wt Pct	Avg Minimum P, Wt Pct
10	0.246	0.081	0.008
2	0.378	0.080	0.006
5	0.488	0.072	0.009
6	0.690	0.190	0.010
2	0.910	0.125	0.016

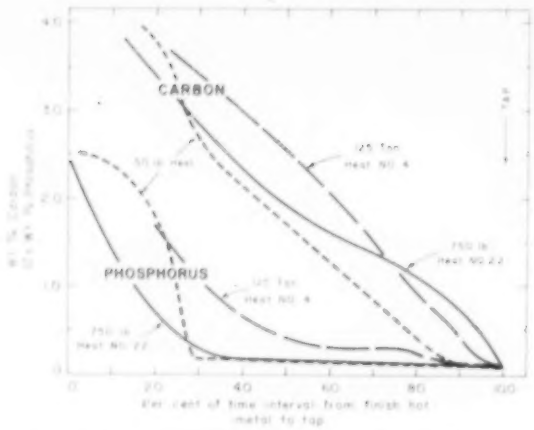

Fig. 11—A comparison of carbon and phosphorus elimination in 50 lb, 750 lb, and 125 ton heats. As can be seen, the differences are small.

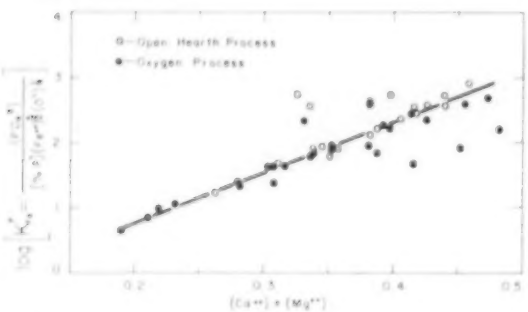

Fig. 12—A comparison of dephosphorization in the open hearth process and the oxygen process. Scatter is approximately the same.

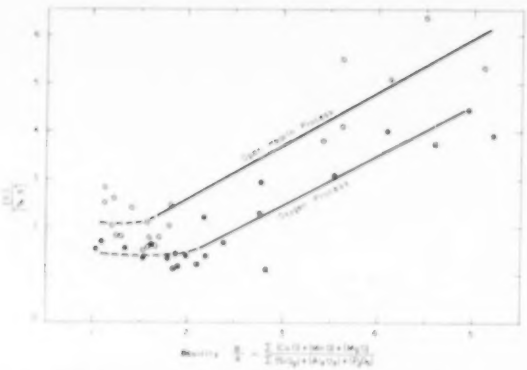

Fig. 13—A comparison of sulfur distribution in the open hearth process and the oxygen process slag-metal system.

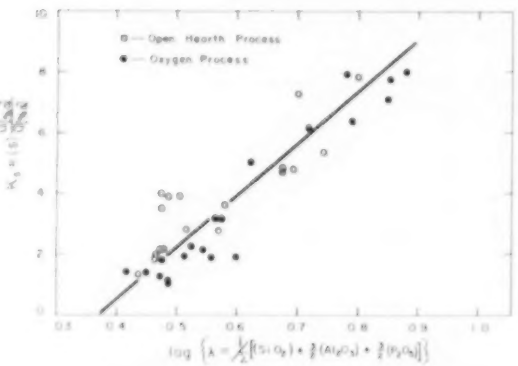

Fig. 14—A comparison of desulfurization in the open hearth process and the oxygen process; the Turkdogan method being used.

nace to determine the operating characteristics of the process in a large hearth type vessel.

Two modifications were made to the furnace. The level of the flush hole was dropped to accommodate the 125 ton heat size and the flush opening was enlarged to permit rapid slag run-off. The second modification was made to permit the simultaneous introduction of three oxygen lances. This was done by providing a second hole, somewhat above the existing wicket hole, in the middle three furnace doors.

Furnace operation

After two preliminary heats were made, the following practice was adopted. The furnace was brought up to slagging temperature in order to approximate the conditions that would be expected after tapping a heat. The tap hole was closed and the fuel was turned off. The dampers were opened to permit removal of waste gases through both regenerators. As in the 750 lb heats, the cold charge was introduced first. Limestone, ore, burnt lime and finally scrap were charged in that sequence. The hot metal addition was made on top of the cold charge and lancing was begun immediately with oxygen containing 95 pct O_2. The oxygen was introduced essentially at the slag-metal interface at the highest rate attainable. At times it was possible to blow through three lance pipes, but because of lance changes the largest portion of the heats were blown with two lance pipes in the bath. Oxygen was injected continuously through to tap.

Appropriate slag and metal samples were taken to determine composition changes during flushing and during refining. Bath temperatures were measured from time to time with a Pt-Pt, 10 pct Rh thermocouple. Moreover, complete furnace logs were kept of the four heats.

Following the hot metal addition there was a light boiling action in the furnace. The bath was open to receive oxygen lances and remained open at the lances throughout the heat cycles. In the early stages of the first two heats the bath tended to freeze out toward the ends and front wall of the furnace. This was overcome on the last two heats by increasing the oxygen blowing rate.

Very little slag formed during the hot metal addition but the slag developed rapidly when oxygen lancing was begun and the heats began to flush a few minutes later. The flush slag was viscous at first but gradually became fluid and ran off very satisfactorily. The late flush slags had a tendency to be foamy but this was successfully combatted by spar additions.

Up to 35 pct of the phosphorus burden and up to 50 pct of the manganese burden were removed in the flush. However, the concentrations of maganese and phosphorus were about the same as in open hearth flush slags. Flush slag weights, calculated by the phosphorus and manganese method, ranged from 120 to 170 lb per ton of ingots. This is comparable to open hearth heats made with 56 pct hot metal but is considerably lower than the amount of slag which

Table III. Effect of Initial Sulfur Level on Sulfur Elimination

No. of Heats	Avg S in Hot Metal, Wt Pct	Avg Minimum S, Wt Pct	S Removed, Pct of Total
10	0.036	0.017	53
5	0.055	0.021	62
7	0.062	0.028	55
4	0.074	0.030	60
2	0.100	0.036	64

Table IV. Effect of Oxygen Blowing Rate on Fuel Requirements

Heat No.	Oxygen Blowing Rate, Cfm	Fuel Oil Required, Gal
1	1170	468
2	1430	155
3	1600	58
4	1980	none

Table V. Hot Metal and Steel Analyses for 125 Ton Heats

	Range of Hot Metal Analysis		Range of Ladle Analysis	
	Wt Pct P	Wt Pct S	Wt Pct P	Wt Pct S
3 low carbon heats, Nos. 1, 2, & 4	0.244-0.256	0.024-0.025	0.008-0.010	0.013-0.019
1 medium carbon heat No. 3	0.259	0.028	0.011	0.025

Table VI. Effect of Oxygen Blowing Rate on Carbon Drop and Heat Time

Heat No.	O_2 Blowing Rate, Cfm	Carbon Drop Pts per Min	Heat Time, Hr, Chg. to Tap
1	1170	2.21	4.50
2	1430	2.65	3.30
3	1600	3.10	2.92
4	1980	3.41	2.83

Table VII. Production Data, 125 Ton Heat No 4

Charge Material, Lbs			
Limestone	19,500	Heat time, hr chg. to tap	2.83
Sinter	17,000	Productivity, tons per hr, chg. to tap	40.1
Burnt lime	3,600	Oxygen consumption cf per ton	2100
Scrap	9,600	Oxygen efficiency, pct	98.6
Hot metal	245,000	Ingot production, tons	113.4
Total metallics	265,650		
		Ingot yield, pct	86.0
		Iron yield, pct	95.6

was removed in the 750 lb heat tests. The lower slag weight in the large heats was caused by an inability to remove most of the slag at flush.

One of the objectives of the experiment was to find the minimum oxygen blowing rate at which external fuel was not required. This was done by increasing the blowing rate from heat to heat and measuring the fuel required to shape up the heats. Fuel oil was used in the first three heats to shape up the refining slags which were cold, viscous and not fully melted. However, the slag was fluid when the bath carbon concentration was 1 pct in Heat No. 4 and the slag at tap was in very good condition.

Table IV shows that fuel is not required in the process at blowing rates at or above 1980 cfm. This demonstrates the particularly important feature that the heat evolved from oxidation reactions is sufficient for carrying out the process in large hearth type furnaces. Furthermore the required blowing rate is somewhat below that practiced in oxygen converter heats of less than half the size. That the tap temperature of Heat No. 4 was 3025°F is further verification that the blowing rate on that heat was high enough to carry out the process without supplementary fuel.

Results of 125 ton heat trials

Three of the heats were made to low carbon rimmed steel specifications and one heat was made to a medium carbon semi-killed specification. The ladle analyses of Table V show the low levels of phosphorus and sulfur which were obtained on the heats. These levels of final phosphorus and sulfur are at least as low as those of open hearth steel. Moreover, the nitrogen concentration in ladle samples ranged from 0.003 to 0.005 pct N, which is the normal open hearth nitrogen range. This is somewhat higher than that obtained on the 750 lb heats, presumably because the oxygen used on the large scale heats was of lower purity.

The rates of carbon drop and heat times were largely controlled by the oxygen blowing rate as shown in Table VI. Heat No. 4 was blown as rapidly as was possible with the available facilities. Optimum heat time for the process would be that determined by the maximum rate of refining at which carbon elimination would be under control. It is felt that heat times of 1 to 1½ hr would be about optimum. This would require an oxygen blowing rate of double that obtained in Heat No. 4.

A specific example will serve to demonstrate the various operating and chemical features of the process. Heat No. 4, a low carbon heat, has been chosen since it was the only 125 ton heat which was made as is visualized for commercial practice. Table VII shows pertinent production data from Heat No. 4. Sinter made up about 7 pct and scrap was about 4 pct of the hot metal charged. The oxygen consumption, oxygen efficiency and yield were about the same as has been reported for other oxygen steelmaking processes.

Fig. 10 shows the courses of refining of carbon, phosphorus and sulfur. It is important to note the uniform rate of carbon drop, which is largely a result of nearly constant oxygen blowing rates. A second feature is the rapid early elimination of phosphorus and the somewhat constant level of sulfur which persists until late in the heat. As was expected, phosphorus removal late in the heat was highly dependent on slag conditions. This was also true for sulfur elimination. Sharp drops in phosphorus and sulfur were experienced late in this heat when the slag cleared up.

The general pattern of refining reactions is apparently not changed appreciably by heat size or by heat time. Fig. 11 demonstrates this by comparing the courses of refining of phosphorus and carbon in 50 lb, 750 lb, and 125 ton heats. The refining times with the three heat sizes ranged from about 20 min to about 3 hr with only a minor effect on the courses of refining. Much more important to refining is the completeness of flush slag removal. Slag removal in the 750 lb heat was under the best control of those shown and therefore had a more rapid early phosphorus drop. Commercial size furnaces would probably have to be rocking or tilting types in order to remove flush slag most completely.

Dephosphorization and desulfurization

Slag and metal data from the open hearth and the oxygen process can be used to compare the relative physical chemical natures of the slag-metal systems. The open hearth data of Elliott and Luerssen[9] were used for comparison of data from the 125 ton oxygen heats. The correlations selected were those for phosphorus and sulfur, since they give the best insight into the chemistry of the steelmaking slag-metal system.

The ionic treatment of Herasymenko and Speight[10] was used to compare phosphorus oxidation in the

two processes. Fig. 12 is a plot of the log of the phosphorus oxidation equilibrium constant, K_P,[P], as a function of basicity expressed as the sum of calcium ion and magnesium ion fractions. The line of best fit represents equilibrium at about 1610°C. It is noteworthy that only in highly basic slags is there a divergence toward poorer dephosphorization in the oxygen process data. These highly basic slags were also late refining slags when the metal temperature was highest—up to 1665°C. The observed poorer dephosphorization is probably only confirmation of the observed high refining temperatures.

The behavior of sulfur is not nearly as clear cut as the behavior of phosphorus. A plot of sulfur distribution ratio $\frac{(S)}{[\text{pct S}]}$ as a function of slag basicity shows quite clearly that sulfur distribution ratios are higher in the open hearth than in the oxygen process. This plot is presented in Fig. 13. This behavior was also observed by Tenenbaum[10] who reported lower $\frac{(S)}{[\text{pct S}]}$ in open hearth heats blown with oxygen than those not blown with oxygen. This behavior therefore appears to be related, in some manner, to oxygen blowing.

For this reason the correlation method of Turkdogan[14] for desulfurization was tried in an attempt to determine if a clear separation of the data persisted when oxygen activity is a feature of the correlation. Turkdogan considered the desulfurization reaction: $[S] + (O) \rightleftharpoons (S) + [O]$ and wrote an equilibrium constant, $K_s = (S)\frac{A[\text{pct O}]}{A[\text{pct S}]}$. He found that this correlated well with the total acids in the slag and therefore plotted K_s as a function of the log of the reciprocal of the sum of acids expressed as $\Sigma\ (SiO_2) + 1.5\ (Al_2O_3) + 1.5\ (P_2O_5)$.

The open hearth and oxygen process data plotted in Fig. 14 fall within Turkdogan's scatter band for 1600°C. More important to this study is that the open hearth data and the oxygen process data are no longer separated. One can therefore explain most of the separation of the open hearth data and oxygen process data which was shown in Fig. 13 by differences in sulfur and/or oxygen activity in the metal bath. Tenenbaum's findings[10] would indicate that the differences in oxygen activity in the metal are controlling.

Perhaps the most important result of this analysis is that the slag-metal system in the oxygen process is as close to equilibrium as that of the open hearth with regard to phosphorus and sulfur.

Summary

An oxygen steelmaking process has been described which is more adaptable to American raw materials than either the conventional Thomas process or the oxygen steelmaking processes which have been developed from the Thomas process. Experiments have been conducted in small and large heats to determine the operating and refining characteristics of the process.

In operating the process, hot metal is poured on a cold charge consisting of lime and/or limestone, ore, and steel scrap. Oxygen is introduced essentially at the slag-metal interface and blowing is continued through to tap. A slag is flushed in the early stages, thus removing a large portion of the phosphorus burden.

Sixty-one heats of 750 lb size were made to study various features of the process. Analysis of the results of these experiments shows that the process has an unusual ability to remove phosphorus very rapidly in the initial stages of the heat, due to the fact that a highly oxidized flush slag is removed. Low phosphorus, low sulfur, low nitrogen steel high in carbon can be produced directly from hot metal containing up to at least 0.7 pct P and up to 0.07 pct S. The effect of the initial phosphorus concentration on the final phosphorus concentration in the steel is not appreciable until the initial phosphorus exceeds 0.7 pct P. The rate of sulfur elimination was found to be directly proportional to the hot metal sulfur concentration.

Four heats of about 125 ton size were made in a modified open hearth furnace. They also demonstrated the early phosphorus drop and, in general, confirmed the patterns of refining found in the 750 lb heats. Examination of the data indicated that these heats closely resembled open hearth flush practice heats in the chemistry of phosphorus and sulfur elimination.

Conclusions

The objectives of the program have been stated early in this paper. The following conclusions can be drawn with reference to the objectives as outlined previously: 1) The process can produce 0.010 pct P steel from pig iron containing as much as 0.7 pct P or above. 2) High carbon low phosphorus steel can be made without large amounts of recarburizers. 3) The product is low in nitrogen (trace to 0.003 pct N when blown with high purity oxygen and .003 to .005 pct N when blown with 95 pct O_2. 4) The phosphorus concentration reaches low levels while the carbon is still high and steel compositions identical to basic open hearth steels are produced. Due to the low sulfur burden, very low sulfur steels can be produced from most American pig irons. 5) The process does not require external heat for refining. 6) The process can be carried out in large hearth type furnaces.

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by W. L. Kerlie
J. H. Richards

ORIGIN AND ELIMINATION OF HYDROGEN IN BASIC OPEN-HEARTH STEELS

The variation in hydrogen content of basic open-hearth steels during refining and the effect of changing from steam to air atomization were studied. The water content of the furnace atmosphere, the slag basicity, and the degree of oxidation of the slag-metal system largely control the hydrogen in the steel.

SMALL amounts of hydrogen have an adverse effect on the ductility of steel and a wide range of hydrogen contents has an adverse effect on the internal soundness of both ferrous and nonferrous castings. This has been of major concern to the metal industry, both manufacturers and fabricators, for many years. As one of the results of continuing investigations of the hydrogen problem, much has been learned about methods of reducing the hydrogen content of liquid metals below the relatively high levels that are normally associated with such phenomena as rising ingots and excessive porosity in sand casting. However, it was not until a reliable and simple method for sampling and analyzing liquid metal was developed that much progress was possible in quantitatively evaluating the effect of steelmaking practice on hydrogen contents at levels below 6 to 8 ppm. Throughout all the work described in the following presentation the Geffner pintube technique was used to obtain samples of liquid metal[1,2] and the tin-fusion method, developed at Massachusetts Institute of Technology,[3] was used to analyze the samples.

Before attempting a systematic experimental program for minimizing the hydrogen content of open-hearth steels, it was necessary to determine the variation in hydrogen in the open-hearth bath during the normal processing of a heat.

The logs of ten heats are illustrated in Figs. 1 through 7. The number at each point on the graphs refers to the number of pintube samples analyzed for hydrogen.

An increase in the hydrogen content of the liquid metal during the early period of refining is apparent in all heats. There is evidence of a decrease in hydrogen later in the refining period, see Fig. 2, for example. Therefore, the existence of a maximum hydrogen content at some intermediate time during the refining period is anticipated.

To test for the existence of a maximum, the data illustrated in Figs. 1 to 5 were grouped together so that they could be examined on a collectively comparable basis. The grouping was effected, as illustrated in Fig. 8, by superimposing Figs. 1 to 5 so that the apparent hydrogen maxima coincided at a fixed position, indicated by the zero on the time axis. Also, by vertical adjustment until the graphs appeared to the eye to be superimposed, the hydrogen scale was made to show the change in hydrogen content. That is, a standard amount was subtracted from the hydrogen values for each heat. Therefore, Fig. 8 represents a generalized presentation of the data and, for this reason, cannot be used to predict the actual hydrogen content of the bath during refining, but rather to show the probable rate of change in hydrogen during refining.

Statistical examination of the grouped data in Fig. 8 shows that the apparent increase and subsequent decrease in hydrogen are real and confirms the existence of a maximum in general. The average increase in hydrogen during the early period of refining is between 0.8 and 1.3 ppm per hr, and the

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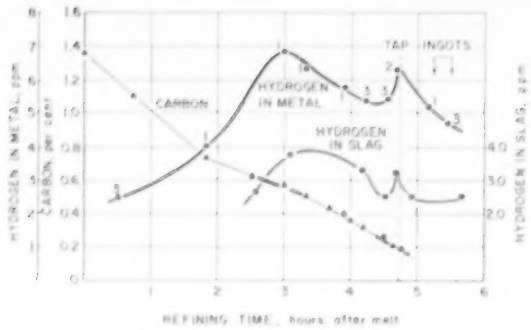


Fig. 1—Variation in hydrogen during refining of heat *A*-1.

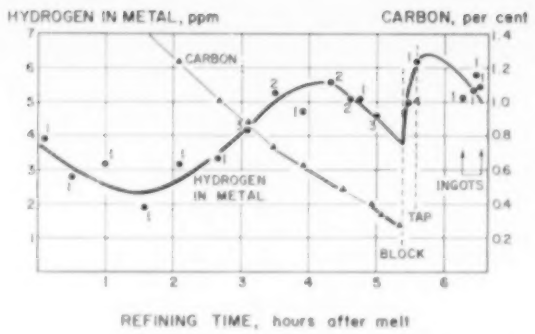


Fig. 2—Variation in hydrogen during refining of heat *A*-2.

average decrease in hydrogen in the late period of refining is at a rate between 0.02 and 0.70 ppm per hr. These rates represent 95 pct confidence limits and the mean rates are represented by the slopes of the regression lines illustrated in Fig. 8.

Because of the much shorter refining periods in heats *B*-1 to *B*-5, the data were insufficient to establish the slope of the hydrogen-time curve with any degree of certainty.

Effect of Rate of Carbon Removal—The rate of carbon removal, as represented by the slope of the carbon-time curve, does not appear to have any marked effect on the rate of rise in hydrogen toward the maximum. For example, in Fig. 4 the rate of carbon removal during the first 2 hr of refining is fairly steady at approximately 0.3 pct per hr, whereas in Fig. 5 the rate of carbon removal during the same period is about 0.6 pct per hr, and yet the average slopes of the hydrogen lines are quite similar (1 ppm per hr respectively). However, the maximum hydrogen does appear to be influenced by the rate of carbon removal. This tentative conclusion is based on the data of Table I and is demonstrated in Fig. 9. The rate of carbon removal was calculated from the differences in carbon content and time as shown in Table I and as illustrated by the thick portion of the carbon line in Figs. 1 through 5. The solid line in Fig. 9 shows that the hydrogen maximum decreases with increasing rate of carbon removal and seems to approach an asymptote at approximately 4.0 ppm.

At the end of refining, there is a roughly similar relationship between the rate of carbon removal and hydrogen, and this is also illustrated in Table I and the dashed curve in Fig. 9. As a zero rate of carbon removal is approached, extrapolated values of hydrogen of about 7 ppm are indicated.

Effect of Water Vapor in Furnace Atmosphere—Because the water vapor in the furnace atmosphere was suspected to be a primary source of hydrogen, an attempt was made to correlate the hydrogen in the bath and the calculated H_2O in the furnace atmosphere.

Table II compares the hydrogen in the bath with the H_2O in the atmosphere for plants *A* and *B* when different fuels were used. The ratio $\frac{H}{\sqrt{H_2O}}$ appears to be roughly constant and indicates that, although other factors may also be effective, the H_2O in the furnace atmosphere is probably the major source of the hydrogen in steel.

Effect of Level of Oxidation—Figs. 2, 3, and 5 show that when the heat is blocked there is a measurable increase in hydrogen content. A study was made in plant *C* in which a heat was blocked and the blocking period extended to 27 min. During the block, samples were taken periodically for hydrogen analyses.[5] The results of this experiment are illustrated in Fig. 10 and show that the hydrogen content rises during block and may reach a value in the region of 7.0 ppm.

The apparent correlation of maximum hydrogen and rate of carbon boil, and the increase of hydrogen in the bath during a furnace block, suggest that the level of oxidation of the slag or slag and metal system can influence the hydrogen content of the liquid metal.

Other Possible Sources of Hydrogen—To minimize the possibility of overlooking other significant sources of hydrogen, the hydrogen content of the materials normally added to the furnace and ladle was determined.

Table I. Influence of Rate of Carbon Boil on Hydrogen Content of Basic Open-Hearth Heats *A*-1 to *A*-5

	At Maximum H Content				Before Block			
Heat No.*	Hydrogen in Bath, Ppm	Change in Carbon, Pct	Time Interval, Min	Rate of Boil, Pct C per Hr	Hydrogen in Bath, Ppm	Change in Carbon, Pct	Time Interval, Min	Rate of Boil, Pct C per Hr
A-1	6.05	0.62 to 0.50	50	0.14	5.42	0.25 to 0.19	15	0.24
A-2	5.62	0.75 to 0.49	60	0.26	4.66	0.39 to 0.28	25	0.26
A-3	5.04	0.84 to 0.53	58	0.32	4.41	0.40 to 0.15	33	0.46
A-4	6.70	0.62 to 0.50	37	0.19	3.98	0.33 to 0.21	20	0.36
A-5	4.40	0.85 to 0.31	60	0.54	3.90	0.31 to 0.17	20	0.42

* See appropriate figure number, that is, samples from heat *A*-1 are shown in Fig. 1.

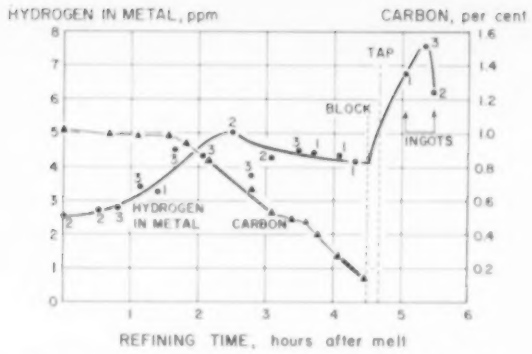


Fig. 3—Variation in hydrogen during refining of heat A-3.

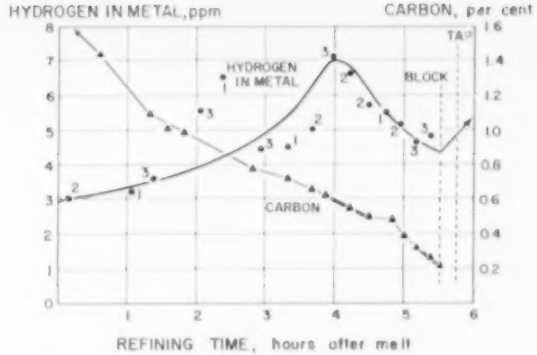


Fig. 4—Variation in hydrogen during refining of heat A-4.

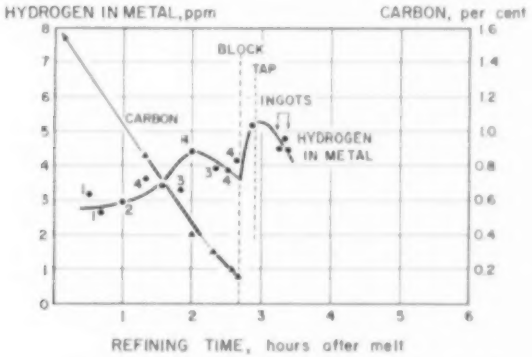


Fig. 5—Variation in hydrogen during refining of heat A-5.

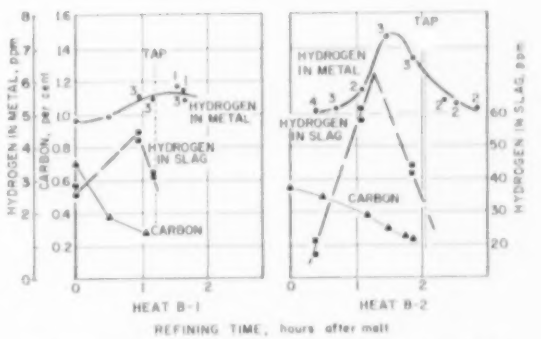


Fig. 6—Variation in hydrogen during refining of heats B-1 and B-2.

A list of the hydrogen contents of such materials is given in Table III. Because of kish formation, it was difficult to obtain reliable samples of hot metal for hydrogen analysis. However, the results indicate that the hydrogen content of the mixer iron is between 2.5 and 4.5 ppm. The outstanding result from these analyses is the value of 96 ppm reported for low-carbon ferrochrome. On this particular sample, the hydrogen was checked at 96 ppm. Calcium silicide and ferrovanadium contain relatively large amounts of hydrogen, about 30 ppm.

Approximate calculations have been made of the increase in hydrogen content in the steel that could result from the hydrogen content of the additions to the furnace at block and to the ladle at tap. The results are shown in Table IV, and indicate that, with certain exceptions, the increase is small and may be ignored in the present study. The possible increase in the hydrogen content of steels that have been made with ladle additions of anthracite has not been estimated.

It may be argued that combined water in lime and ore additions raises the hydrogen content of the bath. However, since approximately 100 to 150 lb of water vapor per min is passing through the furnace in the combusted gas, it is doubtful that this rise could be permanent.

In summarizing the results of these exploratory studies, it has been demonstrated that the water content of the furnace atmosphere is possibly the major source of the hydrogen in the steel and that the degree of oxidation of the slag-metal system may be an important factor affecting the transfer of hydrogen from the atmosphere to the liquid metal.

Table II. Hydrogen Content of Steel and H_2O in Furnace Atmosphere

Heat No.	Hydrogen in Steel, Ppm	H_2O in Furnace Atmosphere, Pct	$H/(H_2O)^{1/2}$	Remarks
Basic Open-Hearth Heats in Plant A*				
A-1	5.4	12.0	1.6	Sampled before tap Tapped open
A-2	4.7	12.4	1.3	Sampled before block
A-3	4.6	11.5	1.3	Sampled before block
A-4	4.1	12.6	1.2	Sampled before block
Average	4.7	12.4	1.3	
Basic Open-Hearth Heats in Plant B				
B-1	5.5	17.8	1.3	Sampled before tap Tapped open
B-2	6.7	19.4	1.5	Sampled before tap
B-3	5.8	18.9	1.3	Tapped open
B-4	4.4	19.2	1.0	
B-5	4.8	19.4	1.1	
Average	5.4	18.9	1.2	

* No fuel data available for calculating H_2O in furnace for heat A-5.

† The average hydrogen content for the pintubes taken 5 min before tap was used in calculating the ratio $H/(H_2O)^{1/2}$. It was not possible to determine the H_2O in the furnace atmosphere at tap because of rapidly changing firing conditions.

Controlled Experiments

By deliberately varying the factors that appeared to influence the hydrogen content, it should be possible to establish their relative importance. Because steam atomization contributes about 40 pct of the H_2O in the furnace atmosphere and because the hydrogen content of oil is about twice that of tar it was decided to study the effect of changing from steam to air atomization and from the standard oil-tar firing at plant *A* to 100 pct tar firing. Preliminary calculations indicated that air atomization and 100 pct tar firing would give about 6 pct H_2O in the furnace atmosphere compared with 13 pct H_2O for normal practice.

Materials and Experimental Work—A new burner that could be used either for air atomization or for steam atomization was installed in one of the furnaces in plant *A*. Two compressors, each rated at 600 scfm, supplied the air at 120 psi and 170°F for atomization. Records were made of the flow of 1) primary combustion air, 2) steam for atomization, and 3) oil and/or tar; and sling psychrometer readings were obtained of the humidity of the air. None of the heats was blocked.

Carbometer, pintube, and slag samples were taken periodically during the latter part of the refining period and immediately before tap. Immersion temperature readings were taker, when possible, immediately before sampling. The usual records of the time of additions to the bath and the times of sampling were obtained for each heat.

A total of ten experimental heats was made under the conditions shown in Table V.

The determination of the rate of carbon removal was based on the following data: 1) carbon test results by the carbometer method and time of sampling, and 2) check carbon determinations by the combustion method, by using drillings from the carbometer samples when regular combustion-carbon samples were not available.

The individual hydrogen contents of the pintube samples and the average hydrogen values are quoted in Table VI, which also lists the carbon content and the temperature of the bath when the pintube samples were taken.

Calculating the Water Content of the Furnace Atmosphere—The calculation of the water content of the furnace atmosphere was based on the following:

Table III. Hydrogen Content of Additions

Material	Grade	Plant	Hydrogen, Ppm
Ferromanganese	Medium-carbon	*A*	9.5, 7.0
Electrolytic manganese	—	*D*	12.3
Silicomanganese	—	*A*	8.7, 13.5
Ferrochrome	High-carbon	*A*	6.3, 4.6, 8.8, 8.5
Ferrochrome	High-carbon	*D*	20.8
Ferrochrome	Low-Carbon	*D*	4.2
Ferrochrome	Low-Carbon	*A*	96.0 (checked)
Ferromolybdenum	High-carbon	*A*	8.4
Ferrovanadium	—	*A*	32.1, 30.9
Calcium silicide	—		35.2, 27.8, 45.8
Electrolytic nickel	—		5.0, 5.4
Aluminum	Wire	*A*	12.5
Aluminum	Wire	*D*	13.2
Aluminum	Star	*D*	4.7, 5.3
Fluorspar	Star	*D*	0.93 pct H_2O
Hydrogen Content of Hot Metal			
Mixer iron	Regular sulfur	*A*	2.55
Mixer iron	Low sulfur	*A*	4.31, 4.13
Mixer iron	Low sulfur	*D*	3.57

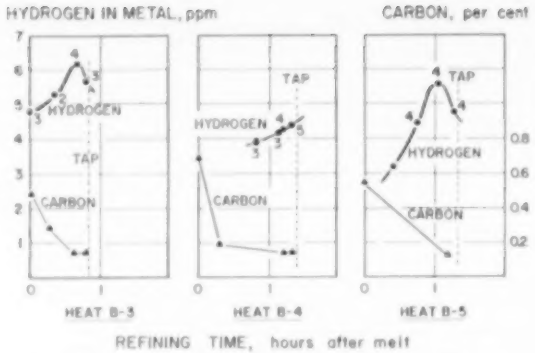


Fig. 7—Variation in hydrogen during refining of heats *B*-3, *B*-4, and *B*-5.

1) Flow of fuel, combustion air, and steam and the capacity of the two compressors used to supply atomizing air.

2) Atmospheric humidity.

3) Analyses of fuel samples taken before and after the series of experimental heats.

4) Calculations of the approximate carbon-removal rates. The most probable carbon-time curve according to the data was drawn for each heat. The tangent to this curve at the appropriate sampling time gave the approximate rate of carbon removal, one of the factors used in the calculation of the H_2O content of the furnace atmosphere. In drawing the carbon-time curves, it was assumed that each addition of ore resulted in an immediate increase in the rate of carbon removal.

5) Estimated weight of steel in the furnace.

The flow rates of the gases composing the furnace atmosphere (H_2O, CO_2, N_2, CO, and O_2) were calculated and then the percentage of H_2O was determined. The presence of CO was assumed when the air supplied to the furnace gases was less than that theoretically required for complete combustion, and the presence of excess O_2 was assumed when the air supplied was greater than that required for complete combustion.

Sampling Errors—Experience had shown that, occasionally, there could be a considerable variation in hydrogen content between individual pintubes from the same spoon sample. A statistical test was applied before any individual hydrogen value was rejected as an outlier. This test was formulated on the results of a study of a group of nine pintubes

Table IV. Calculated Increase in Hydrogen Content Resulting from Hydrogen in Additions

Heat No.	Hydrogen Content, Ppm: Furnace Additions, Increase	Hydrogen Content, Ppm: Ladle Additions, Increase
	Plant *A*	
A-1	—	0.2
A-2	0.1	0.1
A-3	0.1	0.4
A-4	0.1	0.1
A-5	0.1	0.1
	Plant *B*	
B-1	—	0.1
B-2	—	0.1

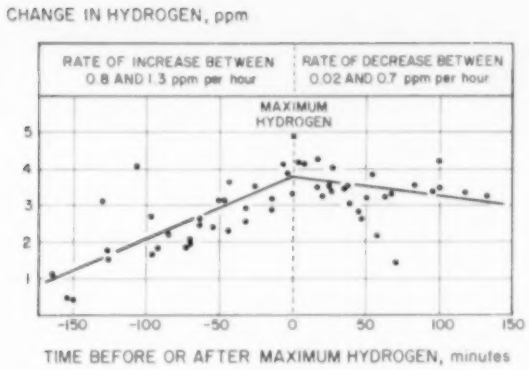

CHANGE IN HYDROGEN, ppm
RATE OF INCREASE BETWEEN 0.8 AND 1.3 ppm per hour
RATE OF DECREASE BETWEEN 0.02 AND 0.7 ppm per hour
MAXIMUM HYDROGEN
TIME BEFORE OR AFTER MAXIMUM HYDROGEN, minutes

Fig. 8—Approximate rates of increase and decrease in hydrogen during refining to heats A1 to A5.

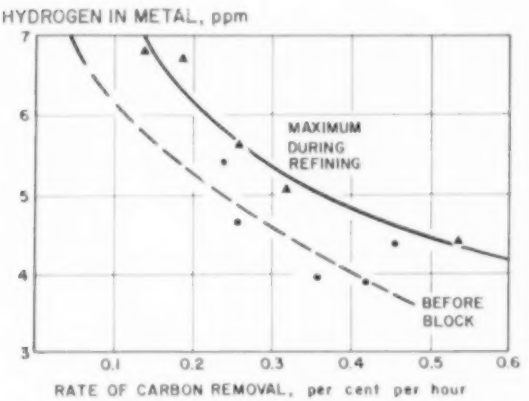


Fig. 9—Variation in hydrogen with rate of carbon removal; heats A-1 to A-5.

sampled simultaneously in the plant and 33 pintubes sampled simultaneously in the laboratory. These 42 samples covered a range of values similar to that illustrated in Table VI.

The following deviations from the sample mean were used as critical values to test for outliers: 3 pintubes analyzed, ±1.00; 4 pintubes, ±1.06; 5 pintubes, ±1.10; and 6 pintubes, ±1.12 deviation. Thus, in sample *A*-8(a) of Table VI, the average of all four samples is 4.22, and the value of 6.41 is suspect. Since the 2.19 deviation of this value from the average exceeds the 1.06 critical value, the 6.41 value is rejected and the average taken as 3.49.

In Table VI, the values that have been rejected are marked with an asterisk. For samples *A*-9(a) and *A*-11(a), the respective values of 11.00 and 7.70 ppm were rejected as being impossibly high compared with other samples for these heats, and for sample *A*-12(d), the 1.24 ppm value was rejected as being impossibly low. The error in hydrogen analysis is known to be about ±0.2 ppm.

Table V. Conditions for Ten Experimental Heats

Fuel	Atomization	Heat Nos.
Oil and tar	Steam	*A*-6, *A*-11
100 pct tar	Steam	*A*-8, *A*-13, *A*-14
Oil and tar	Air	*A*-7, *A*-9, *A*-15
100 pct tar	Air	*A*-10, *A*-12

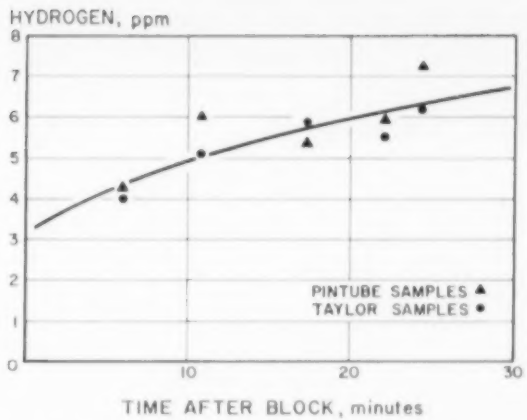


Fig. 10—Increase in hydrogen content of heat C1 after block.

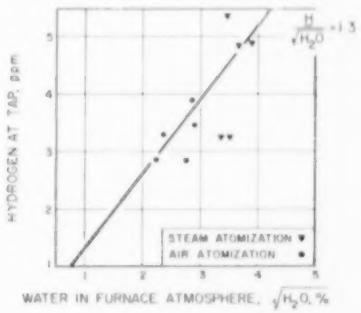


Fig. 11—Influence of H_2O in furnace atmosphere on hydrogen in bath at tap; heats A6 to A15.

Slag Basicity and Degree of Oxidation—Slag samples were taken on all heats and were analyzed for CaO, MnO, SiO_2, P_2O_5, FeO, and Fe_2O_3. The basicity of the slag was calculated according to the expression given by Kerlie[4]

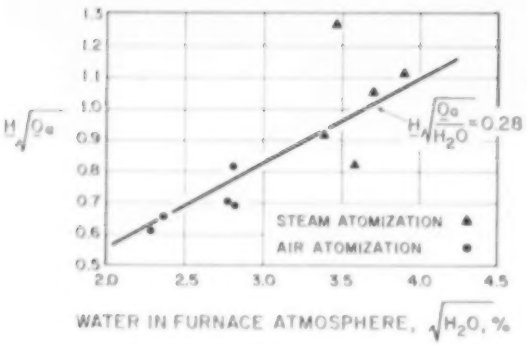
$$\beta = \frac{\text{CaO} + 0.39\ \text{MnO}}{0.93\ \text{SiO}_2 + 1.18\ \text{P}_2\text{O}_5}$$

Although the basicity may be represented in other ways, it has been well established that the activity of the FeO in the slag decreases with increasing basicity.[4, 5] Since experience had indicated that the hydrogen content tended to decrease with increasing degree of oxidation, the latter was calculated[4] from a knowledge of the basicity of the slag, the total iron oxide in the slag expressed as FeO, and the bath temperature. The calculated degree of oxidation may be defined as the oxygen available from the slag or, as described by Darken,[6] the oxygen content of the metal immediately adjacent to the slag, designated in this report as O_s.

Effect of Varying the H_2O in the Furnace Atmosphere— In Fig. 11, a plot is shown of the variation in hydrogen with the water vapor in the atmosphere. The use of the root sign is in accordance with the dissociation of water vapor in contact with liquid iron, namely

$$\tfrac{1}{2}\ \text{H}_2\text{O} = \text{H} + \tfrac{1}{2}\ \text{O}. \qquad [1]$$

It is interesting to note that the line corresponding to $\frac{H}{\sqrt{H_2O}} = 1.3$ (1.3 is the average value of heats



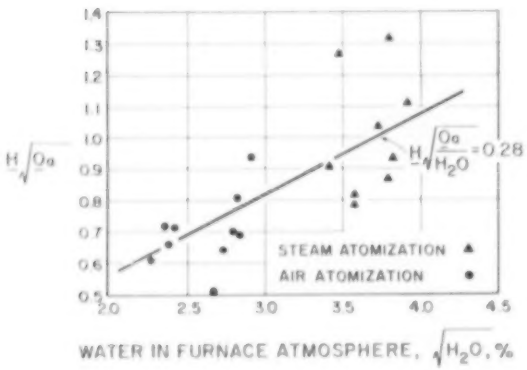


Fig. 12—Influence of available oxygen on the hydrogen content in the bath. a) TOP: Values at tap. b) BOTTOM: Values throughout refining.

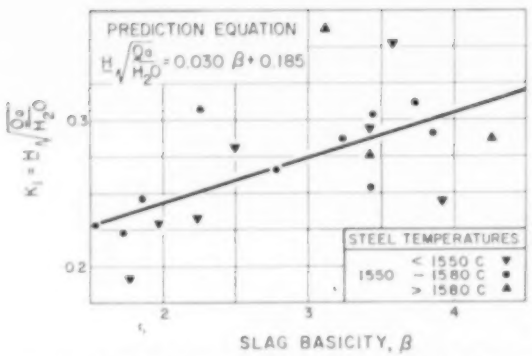


Fig. 13—Variation in equilibrium index, K_1, with slag basicity.

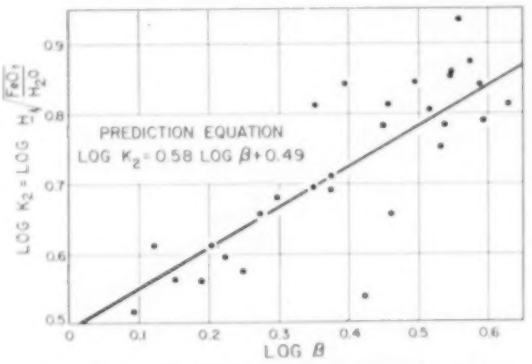


Fig. 14—Correlation between equilibrium index, K_2, and slag basicity.

A-1 to A-5 and B-1 to B-5 shown in Table II) is a good fit and indicates that, in the absence of water vapor, the hydrogen content of liquid steel would be zero.

Fig. 11 shows that a hydrogen content of 4.7 ppm at tap is to be expected under normal conditions (steam atomization and oil-tar firing) when the water vapor in the furnace atmosphere is 13 pct. A 50 pct reduction in this value (obtainable with air atomization and 100 pct tar firing) should therefore decrease the hydrogen content to 3.3 ppm.

Effect of the Degree of Oxidation—According to Eq. 1, a good correlation should be obtained between $H\sqrt{O_a}$ and $\sqrt{H_2O}$. This is shown in Fig. 12a, which applies to the samples at tap and in which the oxygen concentration term is represented by the available oxygen, O_a. The index $H\sqrt{\frac{O_a}{H_2O}}$ is approximately 0.28, which means that the hydrogen content can be roughly estimated from the equation

$$H = 0.28\sqrt{\frac{H_2O}{O_a}}. \qquad [2]$$

The data for the other samples (taken before tap) are included in Fig. 12b. Although there appears to be more scatter of the points than in Fig. 12a, a good correlation is still to be observed. A statistical examination of the data of Fig. 12b showed that the correlation was highly significant (significance level, 0.001). Consequently, the available oxygen may be regarded as an important factor influencing the hydrogen content of the bath.

Effect of Slag Basicity—Apart from the influence of the basicity of the slag on the available oxygen, there appears to be a correlation between the basicity and the index $K_1 = H\sqrt{\frac{O_a}{H_2O}}$. The nature of this correlation is shown in Fig. 13. Statistical examination of these data showed the correlation to be such that the following regression equation could be established

$$K_1 = H\sqrt{\frac{O_a}{H_2O}} = 0.03\beta + 0.19. \qquad [3]$$

Although the available oxygen term in Eq. 3 is influenced by slag basicity, it is not correct to assume that there is a forced correlation between K_1 and β. The reasons are as follows:

1) Since an increase in β lowers the oxygen availability,[5] a negative correlation would be obtained if the ratio $\frac{H}{\sqrt{H_2O}}$ remained unaffected by β. The correlation is actually positive.

2) The positive correlation could result from a purely fortuitous increase in O_a with β or an increase in $\frac{H}{\sqrt{H_2O}}$ with β. The data did not indicate any correlation between O_a and β; hence, it is presumed that the ratio $\frac{H}{\sqrt{H_2O}}$ varies with slag basicity.

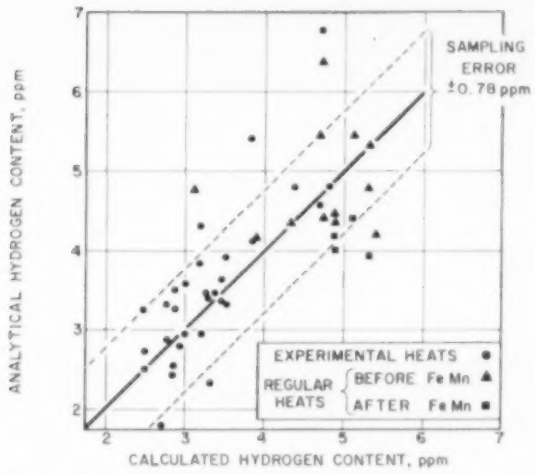


Fig. 15—Comparison of analytical and calculated hydrogen contents.

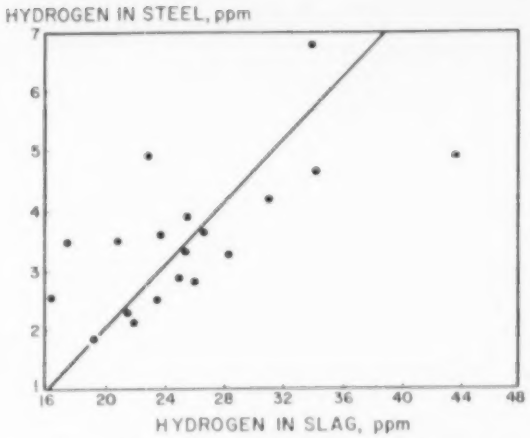


Fig. 16—Variation in hydrogen in steel with hydrogen in slag.

Since the available oxygen is determined by the total FeO and the basicity (if the temperature is constant), a reasonably good correlation should be obtained on plotting the equilibrium index $H\sqrt{\frac{FeO_t}{H_2O}}$ against basicity. Since the steelmaking temperatures in general are between 1550° and 1600°C, no serious error is introduced when FeO is substituted for O_t in the equilibrium index to obtain a new prediction equation. A plot of $\log K_2 = \log H\sqrt{\frac{FeO_t}{H_2O}}$ against $\log \beta$ for the 30 samples for which complete data were available is shown in Fig. 14. In this case the correlation is also significant.

Predicting the Hydrogen Content—The regression equation for the data of Fig. 14 was found to be

$$\log H\sqrt{\frac{FeO_t}{H_2O}} = 0.58 \log \beta + 0.49. \quad [4]$$

This expression may be written in the form

$$H = \frac{3.10\ (\beta)^{0.58}\ (H_2O)^{0.50}}{(FeO_t)^{0.50}} \quad [5]$$

Table VI. Variation in Hydrogen Content and Bath Temperature at Different Carbon Levels

Heat No.	Sample No.	Carbon Pct	Hydrogen in Bath, Ppm, Individual Values	Average	Bath Temperature, °C	Hydrogen in Slag, Ppm
A-6	(a)	0.57	7.43, 6.58, 6.23, 6.92	6.79	1535	34.0
(steam	(b)	0.52	5.14, 3.70, 4.88	4.57	1549	36.2
atomization)	(c)	0.34	5.13, 4.17, 5.29	4.86	1591	22.9
A-7	(a)	0.23	3.64, 3.79, 3.68	3.70		
(air	(b)				1571	
atomization)	(c)	0.10	3.85, 4.14, 3.71	3.90	1574	
A-8	(a)	0.40	2.95, 4.22, 3.31, 6.41*	3.49		21.0
(steam	(b)	0.33	4.92, 3.80, 3.52, 3.43, 4.91	4.12	1546	30.9
atomization)	(c)	0.21	4.30, 4.88, 8.57,* 4.99, 5.17, 6.86*	4.84	1571	43.7
A-9	(a)	0.62	2.76, 11.09*			25.2
(air	(b)	0.44	2.54		1532	16.5
atomization)	(c)	0.21	3.64, 3.24	3.44	1549	17.6
	(d)	0.18	3.95, 3.53, 2.89	3.46	1571	
A-10	(a)	0.59	2.24, 2.50, 2.66	2.47		
(air	(b)	0.46	3.44, 4.76,* 3.16, 3.27, 2.24*	3.29	1504	
atomization)	(c)	0.32			1524	
A-11	(a)	0.81	7.70,* 1.77			19.2
(steam	(b)	0.30	2.05, 2.78	2.42		23.5
atomization)	(c)	0.09	1.98, 2.20, 3.07, 1.79	2.26		21.7
	(d)	0.07	3.48, 3.48, 2.80	3.25	1563	28.2
A-12	(a)	0.91	1.80, 2.27	2.04		21.9
(air	(b)	0.59	3.42, 7.82,* 3.52, 3.68	3.54	1546	23.7
atomization)	(c)	0.46	3.12, 4.50, 3.16, 3.86	3.66	1560	26.2
	(d)	0.26	2.85, 1.24*		1604	
A-13	(a)	0.70	2.89, 2.97	2.93		
(steam	(b)	0.41	3.17, 2.55, 3.11	2.97		
atomization)	(c)	0.26	3.84, 3.51, 3.18, 2.73	3.32	1563	
	(d)	0.20	3.22, 3.62, 2.98	3.27	1577	
A-14	(a)	0.52				
(steam	(b)	0.26	4.30, 3.62, 4.90, 6.23,* 3.89, 4.84	4.31	1566	
atomization)	(c)	0.17	5.33, 5.28, 5.41, 5.46	5.37	1593	
A-15	(a)	0.52	3.19, 3.26, 3.46, 3.37	3.31		25.2
(air	(b)	0.32	6.70*			29.4
atomization)	(c)	0.20	2.99, 3.92, 4.42, 4.02	3.84	1554	25.6
	(d)	0.12	2.17, 3.28, 3.60	2.82	1571	25.1

* Hydrogen value rejected.

and, because the indices for β, H_2O, and FeO_t are all in the region of 0.5, Eq. 5 was simplified to give the expression

$$H^* = 10\beta \frac{H_2O}{FeO_t} \quad [6]$$

to predict the hydrogen content of the open-hearth bath before block.

By plotting $\frac{H^*}{H_2O}$ against $\frac{\beta}{FeO_t}$ and including the data on a series of regular heats, a good correlation was observed. Therefore, Eq. 6 was used to make a comparison of the analytical and calculated hydrogen contents, as shown in Fig. 15. In this diagram, all the available data that included slag analyses have been used. These data represent the ten experimental heats (*A*-6 to *A*-15) and six regularly processed heats for which data were available.

The parallel dotted lines in Fig. 15 represent the reproducibility (0.78 ppm) of an average of four simultaneous pintube samples. This reproducibility represents the deviation of this average from the true mean exceeded only about 5 pct of the time. It is seen that the hydrogen content of the bath can be calculated with reasonable accuracy from a knowledge of the H_2O in the furnace atmosphere and the composition of the slag.

Influence of the Rate of Carbon Removal—Fig. 8 indicated that, during the refining period, the maximum hydrogen content and the hydrogen content before block tended to decrease with increasing rate of carbon removal. However, the data of the experimental heats (*A*-6 to *A*-15) showed no correlation between rate of carbon removal and H, $\frac{H}{\sqrt{H_2O}}$, or $H\sqrt{\frac{O_s}{H_2O}}$.

It would be anticipated, on theoretical grounds, that the hydrogen content of the metal would decrease with increasing rate of carbon removal because of the diffusion of hydrogen from the metal into the CO bubbles.[6] Also, by virtue of the dilution of the H_2O in the furnace atmosphere by the CO from the boiling bath, an increase in the rate of carbon removal could result in a decrease in the hydrogen content.

However, since the rate of carbon removal increases with the available oxygen content,[7] it is possible that its influence is inherent in the expression $H\sqrt{\frac{O_s}{H_2O}}$. It is also possible that during the shaping of the slag the *effective* slag composition is changing in such a manner that the effect of the rate of carbon removal is masked. To determine the effect of varying rates of carbon removal on the hydrogen content of the bath, a controlled experiment to provide sufficient data for a complete analysis of variance and for statistically close estimates of the rate of carbon removal would be necessary. A more accurate sampling technique for hydrogen and a direct method of measuring the H_2O in the furnace atmosphere would be a distinct advantage.

Hydrogen in Slag—The hydrogen content of the steel appears to vary with the hydrogen content of the slag, as shown in Fig. 16. This is in agreement with the observations of Walsh, Chipman, King, and Grant.[7]

Summary and conclusions

During the course of refining in the basic open-hearth, the hydrogen content of the metal rises to a maximum. Thereafter it decreases (sometimes insignificantly) to a lower value immediately before block or tap. The increase toward the maximum probably occurs during the period when lime is going into solution in the slag and appears to be independent of the rate of carbon removal. The maximum hydrogen content itself is related to the rate of carbon removal. In a somewhat similar but less significant manner the hydrogen content at the end of the refining period decreases with increasing rate of carbon removal. Approximate calculations indicate that, with certain possible exceptions, the increase in hydrogen resulting from additions may be ignored.

The following conclusions have been reached as the result of a controlled experiment in the basic open hearth:

1) The water content of the furnace atmosphere is the major source of hydrogen in the bath.

2) The replacement of steam by air for atomizing the fuel will result in significantly lower hydrogen contents in the bath.

3) The degree of oxidation of the bath has an important influence on the hydrogen content.

4) An approximate expression of the combined influence of the water content of the furnace atmosphere, the slag basicity, and the degree of oxidation of the bath on the hydrogen content of liquid open-hearth steel is

$$H^* = \frac{10\beta \cdot H_2O}{FeO_t}$$

where H is the hydrogen content of the bath in ppm, β is the slag basicity, H_2O is the water in the furnace atmosphere in pct by volume, and FeO_t is the total of iron oxides in the slag expressed as FeO in wt pct.

There is no evidence to indicate that the rate of carbon removal by itself influences the removal of hydrogen from the bath, although it would theoretically be expected to do so. The data do not indicate any correlation between temperature and hydrogen content.

Acknowledgments

A considerable amount of the data in this paper was obtained with the help of the Metallurgical Depts. and Power and Fuel Divs. in four of the U. S. Steel Corp. plants. The analyses of the slags for hydrogen were performed at Massachusetts Institute of Technology with the help of Thomas B. King.

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[2] D. J. Carney, J. Chipman, and N. J. Grant: The Tin Fusion Method for the Determination of Hydrogen in Steel. *AIME Trans.*, 1950, vol. 188, pp. 404-413; JOURNAL OF METALS, February 1950.

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[6] L. S. Darken: Kinetics of Gases in Steel. *Proceedings* AIME Electric Furnace Steel Conference, 1948, vol. 6, pp. 55-59.

[7] J. H. Walsh, J. Chipman, T. B. King, and N. J. Grant: Hydrogen in Steelmaking Slags. *AIME Trans.*, 1956, vol. 206, p 1568; JOURNAL OF METALS, November 1956.

Discussion of this paper sent (2 copies) to AIME by Feb. 1, 1958 will appear in AIME *Transactions* Vol. 212, 1958, and in JOURNAL OF METALS, October 1958.

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AIME NEWS

AIME Awards for 1958 Presentation Announced

The following honors will be conferred at the AIME Annual Banquet on Wednesday, Feb. 19, 1958, at the Waldorf Astoria Hotel in New York.

James Douglas Gold Medal to **J. R. Gordon**, "For distinguished contributions to process metallurgy in the field of smelting and refining of nickel, and metallurgical improvements in nickel recovery."

William Lawrence Saunders Gold Medal to **William J. Coulter.** Citation to be announced.

Charles F. Rand Gold Medal to **John F. Thompson.** Citation to be announced.

Anthony F. Lucas Gold Medal to **Carl Ernest Reistle, Jr.,** "for his distinguished achievements in advancing the science of Petroleum Engineering through his own technical contributions and his ability to inspire others; for his forward concepts and his untiring energy in advancing the profession of Petroleum Engineering as a practitioner, administrator, and executive."

Robert H. Richards Award to **Fred D. DeVaney,** "for his contributions to grinding, concentrating and pelletizing; and for his direction of research, metallurgical engineering, and development of methods, for taconite beneficiation."

Robert W. Hunt Medal to **G. W. Healy** and **D. C. Hilty.** Silver medals for paper *Effect of Oxygen Input*

(Continued on page 1550)

AIME Employe Honored By Board for 37 Years Service at Institute

The AIME Board of Directors and the Institute staff took opportunity at the meeting of the Board on November 18 to honor Grace Townsend Ferry—37 years with AIME.

First employed under Bradley Stoughton, AIME Secretary from 1913 to 1921, Mrs. Ferry's memories span the growth of the Institute from 8388 members to its present more than 31,000 members and students, and the attendant diversification of AIME to its present eight Divisions and three Councils operating through three constituent societies.

Mrs. Ferry who lives in Pawling, Dutchess County, N. Y., has commuted an average of an hour and a half each way to work for years, but she seems to thrive on it, and still finds time for her hobby, her garden —blooms from which often add a touch of color to the AIME office reception area.

Resolution in Honor of
GRACE TOWNSEND FERRY

The following resolution to honor Grace Townsend Ferry was voted at the meeting of the AIME Board of Directors on Nov. 18, 1957:

WHEREAS, The Board of Directors of the American Institute of Mining, Metallurgical, and Petroleum Engineers takes note that Grace Townsend Ferry will retire November thirtieth, Nineteen hundred fifty-seven, after thirty-seven years of devoted service,

RESOLVED, that the Board of Directors commends Grace Townsend Ferry, for her loyal and faithful service as Chief File Clerk for the Institute during her entire period of employment; and that the Board of Directors appreciates particularly the unassuming and effective manner in which she carried out the duties of this vital position frequently involving confidential matters.

November 18, 1957 — GROVER J. HOLT, President AIME

The Metallurgical Society Prepares For 1958 Annual Meeting

The Metallurgical Society will hold its first coordinated technical meeting during the AIME Annual Meeting in New York, February 16 to 20. Headquarters hotel will be the Sheraton-McAlpin, Broadway and 34th St., New York.

Education Meeting

A symposium on metallurgical manpower will be held on Sunday afternoon, February 16. This is under the joint sponsorship of the Education Committee and the Committee on the Metallurgical Profession, both committees of The Metallurgical Society. Under discussion will be a report on the formation and initial activities of the new Metallurgy-Ceramics Foundation, under the joint sponsorship of The Metallurgical Society of AIME, ASM, American Ceramics Soc., and the National Science Teachers Foundation. Participants in the program will include G. A. Roberts, chairman of the Special Committee on Manpower for the Metallurgy and Ceramics Profession; Howard A. Meyerhoff, executive director, Scientific Manpower Commission; W. E. Mahin, executive secretary, Special Committee on Manpower, and Chairman of Scholarship and Adult Approach Study Group; and W. R. Hibbard, Jr., chairman, Secondary School Approach Study Group.

It is planned that each of the three constituent societies of AIME hold their own conference on education on Sunday afternoon, and that all three societies join together on Sunday evening for dinner at the Statler Hotel, followed by a meeting sponsored by the AIME Council on Education.

Extractive Metallurgy Division

The Extractive Metallurgy Division has planned an active program of 14 sessions during the AIME Annual Meeting. Sessions will be held

(Continued on page 1551)

AIME Awards

(Continued from page 1549)

Rates in the Decarburization of Chromium Steel. JOURNAL OF METALS, May 1957, pp. 695-707.

J. E. Johnson, Jr., Award to **R. H. White,** "for his contribution in obtaining record production rates on blast furnaces and, also, his substantial contribution to a practical process of desulfurizing hot metal which could, in the future, permit even larger production rates."

Rossiter W. Raymond Memorial Award to **R. J. Charles,** for paper *Energy-Size Relationships in Comminution.* MINING ENGINEERING, January 1957, pp. 80-88.

Mathewson Gold Medal, recipient to be announced.

Robert Peele Memorial Award to **Allen F. Agnew,** for paper *Application of Geology to the Discovery of Zinc-Lead Ore in the Wisconsin-Illinois-Iowa District.* MINING ENGINEERING, August 1955, pp. 781-795.

The award presentation will take place at the MGGD Luncheon on Wednesday, Feb. 19, 1958.

Mineral Industry Education Award to **Charles Elmer Lawall,** "for his outstanding achievements as an engineering teacher and university administrator; and for his continuing interest in the problems of mineral engineering education during his years as Railroad Executive."

Extractive Metallurgy Division Award to **John N. Ong, Jr., Milton E. Wadsworth,** and **W. Martin Fassell, Jr.,** for paper *Kinetic Study of the Oxidation of Sphalerite.* JOURNAL OF METALS, February 1956, pp. 257-263.

Benjamin F. Fairless Award to **Hjalmar W. Johnson,** as "Lifelong contributor to the science and operation of the blast furnace, a leader in civic affairs and in the engineering profession."

John Fritz Medal to **John Robert Suman,** as "Pioneer in the application of engineering principles to the development, production, and conservation of petroleum and natural gas; author; industrial statesman; and one who takes a keen interest and real pleasure in inspiring men to make the most of their talents."

The award is made by the John Fritz Medal Board of Award, composed of representatives from four societies: ASCE, AIME, ASME, and AIEE. The medal is given for "notable scientific or industrial achievement" and the recipient chooses the society of his choice as sponsor for presentation. Dr. Suman has selected AIME and presentation will be made at the AIME Annual Banquet, Feb. 19, 1958.

Hoover Medal to Scott Turner, as "Distinguished Mining Engineer of international experience and reputation, who has served his country and his profession in times of peace and war; active in technical, conservation, and relief work, in promoting sound engineering practices and ethics and the sense of public responsibility.

The Hoover medal is awarded by the Hoover Medal Board of Award for distinguished public service by an engineer. The Board is composed of representatives of four societies: ASME, AIEE, ASCE, and AIME. It will be presented to Mr. Turner at the AIME Annual Banquet on Feb. 19, 1958.

Percy Nicholls Award to **John Blizard:** "In recognition of the outstanding achievement of JOHN BLIZARD in the field of solid fuels, the Fuels Division of The American Society of Mechanical Engineers and the Coal Division of The American Institute of Mining, Metallurgical, and Petroleum Engineers confer upon him The Percy Nicholls Award for 1957.

"He has made many contributions to advance the practice of radiant Superheaters, pulverizer design, forced-circulation steam generators and related fields.

"A Fellow of The American Society of Mechanical Engineers, he has contributed his time generously to the work of the technical societies. A score of patents and almost fifty technical papers have come from his work.

(Continued on page 1552)

AIME

Student Prize Paper Contest

(Undergraduate and Graduate Divisions)

Entry Deadline Date—Sept. 1, 1958

Topics: Mining, Metallurgy, and Petroleum

Exploration • Production • Engineering • Research

Limited to AIME Junior Members and Student Members

Contact your Student Chapter, Chapter Counselor,

Section in your area, or Prof. John Butler,

University of Nevada, Reno, Nevada.

Dues Bills to be Mailed

Notice is hereby given that dues for the year 1958 are payable Jan. 1, 1958, as follows: Members and Associate Members, $20; Junior Members for the first six years of Junior Membership, $12, and thereafter, $17; Student Members (including an annual subscription to a monthly journal), $4.50.

Dues bills will be mailed in December 1957. Prompt payment will assure uniterrupted receipt of the publications desired in 1958. If, for any reason, a bill is not received within a reasonable time, headquarters should be notified.

Annual Meeting

(Continued from page 1549)

on zinc, lead, bismuth, and cadmium; copper; titanium; rare earths, rhenium, beryllium, and thorium; uranium; aluminum and refractories; cobalt and refractories; molten salts; the physical chemistry of sulfide systems; and the physical chemistry of ternary systems. In addition, EMD is planning two sessions to be held jointly with the Minerals Beneficiation Division, Society of Mining Engineers of AIME. These are on hydrometallurgy and on thickening, filtration and flocculants.

A most enjoyable annual feature of the EMD program is the stag luncheon. This year the luncheon will be held in the Crystal Room of the Sheraton-McAlpin Hotel on Wednesday, February 19. At that time, the retiring and incoming Division chairmen and a guest speaker will address the group. Plans for the technical program are being arranged by Albert E. Lee, Jr., chairman of the Papers and Programs Committee.

Institute of Metals Division

The Institute of Metals Division is planning to schedule 14 sessions during the AIME Annual Meeting. The High-Temperature Alloys Committee is sponsoring two sessions on *Processing of High-Temperature Alloys*. The symposium will include contributed papers on melting, casting, working, and heat treating of high-temperature alloys, and the relationship between these processing operations and properties. In addition, short research summaries will be presented by a number of authors.

The Physics and Chemistry of Metals Committee has arranged a one-day symposium on *Impulsive Loading* for the Annual Meeting. The symposium will include three lectures by invited speakers in the morning and short contributed papers in the afternoon. The metallurgical and physical points of view in the field of high-speed pressing will be emphasized, rather than the mechanical. The research summaries in the afternoon will include such topics as delayed yielding, shock-wave phenomena, dislocations at high speeds, strain-rate effects at high strain-rates, and fracture phenomena.

Research seminars and research summaries are planned, based on the submission of abstracts to the IMD Programs Committee, for which the deadline date is November 15. This year the IMD Lecturer is Alan H. Cottrell, deputy head of Metallurgy Div., Atomic Energy Establishment, Harwell, England. His address on the *Theory of Brittle Fracture in Metals* will be given on Wednesday morning, February 19.

Iron and Steel Division

The Iron and Steel Division this year is inaugurating a Division luncheon that will be held on Tuesday, February 18, at the Sheraton-McAlpin Hotel. All members of ISD attending the AIME Annual Meeting are cordially invited to attend. Featured speaker on this occasion will be Tom C. Campbell, editor-in-chief of *The Iron Age*.

The luncheon will follow immediately after the Howe Memorial Lecture to be presented by Max Gensamer of Columbia University.

ISD is planning to hold seven technical sessions. One of these will be a session held jointly with the Minerals Beneficiation Division of the Society of Mining Engineers of AIME on the subject of *Pyrolysis and Agglomeration*. It is planned to present papers on the beneficiation of low-grade iron ores by direct reduction, and the beneficiation of high sulfur and high phosphorus iron research.

The Metallurgical Society Dinner

The annual dinner of The Metallurgical Society will be held in the ballroom of the Sheraton-McAlpin Hotel on Tuesday evening, February 18. At this time, awards will be presented to winners of the J. E. Johnson, Jr., Award, Robert W. Hunt Medal Award, and the Mathewson Gold Medal Award.

Triangle Cruise

Immediately following the Annual Meeting, a triangle cruise on the *Queen of Bermuda* has been planned. The trip will include stops at Bermuda and Nassau. The ship will leave New York on February 21 and return March 1.

1958 AIME Officers

At the November AIME Board of Directors Meeting, the officers of AIME for 1958, and five other Directors named to take office for three-year terms in that year, were officially declared elected. They are as follows: *President-Elect*, Howard C. Pyle; *Vice Presidents and Directors*, A. W. Thornton and J. C. Kinnear, Jr.; *Directors*, E. A. Jones, S. D. Michaelson, B. P. Kantzer, J. P. Hammond, W. R. Hibbard, Jr.

AIME

BOARD OF DIRECTORS

Recent actions taken by the Institute Board of Directors

► Nathaniel Arbiter has been reappointed as one of the AIME representatives on the Engineering Societies Monographs Committee. He will serve a four-year term beginning October 1957.

► It was voted that the same prices should apply for AIME *Transactions* and the Journals (JOURNAL OF METALS, JOURNAL OF PETROLEUM TECHNOLOGY, and MINING ENGINEERING) in 1958 as were in effect in 1957.

► The Four Corners Petroleum Section of AIME was established with the proviso that the Bylaws, Article IV, Section 1, be changed.

► The California Coastal Section of AIME was established with the proviso that the Bylaws, Article I; Article III; Article IV, Section 1; and Article V, Section 3 be changed.

► Nicholas M. Lazar was appointed to represent AIME President Grover J. Holt at the ASME Seminar of Education Committee held in Detroit on Nov. 7 and 8, 1957.

► The Board was informed that the El Paso Metals Section, AIME, had voted unanimously on Oct. 11, 1957, to change its name to El Paso Section, AIME.

► On the recommendation of the Nuclear Metallurgy Committee of IMD, The Metallurgical Society of AIME, Frank Rough, Battelle Memorial Institute, has been appointed to replace J. H. Frye, Jr., as AIME representative on the EJC Atomic Energy Panel. Mr. Frye had resigned.

To the Members of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc.

The regular Annual Business Meeting of the Institute will be held on Tuesday afternoon, the 18th day of February 1958 following the All-Institute Session at the Annual Meeting of the Institute in New York.

AROUND THE SECTIONS

• The Research Center of International Business Machines Corp. at Poughkeepsie, N. Y., was visited by the **Physical Metallurgy Group,** New York Section, on October 16. Following a tour of the laboratories, the 40 AIME members attending were welcomed in the auditorium by Arthur L. Samuel, resident manager of the Research Center.

With John E. Fellows serving as master of ceremonies, various division managers were introduced, who explained some of the problems encountered in developing better computors and other business machines. Ralph W. Landauer discussed X-ray diffraction, lattice vibration in germanium, and ferroelectricity; Seymour P. Keller described their study of strontium sulfide as a phosphor; James M. Brownlow told of magnetics research on ceramic ferrite and single crystal growth; and Geoffrey E. Brock discussed semiconductor research on germanium in transistors for computor circuits. Most of the items discussed by the orientation lecturers have been described in the first four issues of the new publication, *IBM Journal of Research and Development.*

After dinner in the IBM cafeteria, the evening lecture was presented by Cecil G. Dunn, General Electric Company, on *Perfection of Primary and Secondary Recrystallization Grains.*

• The **Connecticut Section** met on September 24 for a plant visit to Fafnir Bearing Co., Newington, Conn., followed by cocktails and dinner at the Indian Hill Country Club, Newington, Conn. The featured after-dinner speaker was Henry Hubbell, chief metallurgist, Fafnir Bearing Co., who discussed *Special Materials and Their Selection for Bearing Applications.*

On November 26, the Section met for dinner on student night, at the Town House in New Haven, Conn. A talk, *Problems in Nuclear Metallurgy,* was given by the guest speaker, K. H. Mair of the University of Rhode Island.

Guest night was held at the meeting of the **San Francisco Section,** on October 9 at the Engineers Club in San Francisco. The guest speaker was Walter T. Selsted, director of research, Ampex Corp., who spoke on *Technical and Economic Aspects of Video Tape Recordings.*

• The fall dinner meeting of the **Lehigh Valley Section** was held on October 25, after cocktails, at the Hotel Traylor, Allentown, Pa. The featured speaker was John F. West, assistant atomic power engineer for Pennsylvania Power & Light Co., who gave a talk on *Corrosion Problems in an Atomic Power Plant Development Program.*

AIME Awards

(Continued from page 1550)

"His concern for and encouragement of young engineers has greatly enriched the lives of all who have had the good fortune to know him.

"We are privileged to honor him as an exceptionally fine scientist, engineer and leader, a generous teacher and an incomparably worthy yet modest gentleman."

The award was presented to Mr. Blizard at the recent CIM-ASME-AIME Solid Fuels Conference in Quebec.

Daniel C. Jackling Award to **Abbott H. Shoemaker,** "for leadership in efficient mine operation, resulting in profits under a fixed gold price in spite of inflationary costs, and for his Lecture, *Planning for Deep Mining at Homestake.*"

Mr. Shoemaker will deliver the Lecture immediately following the MGGD Luncheon on Wednesday, Feb. 19, 1958. The award presentation will take place at the Luncheon.

A certificate to *Alan H. Cottrell,* **Institute of Metals Division Lecturer** for 1958.

A certificate to *Maxwell Gensamer,* **Howe Memorial Lecturer** for 1958.

AIME Lists Class Of 1958 Legion of Honor

Each year at the AIME Annual Banquet in February, those members of the Institute who have continuously maintained their membership for 50 years are given special recognition. They are seated at the head table as guests of AIME and are added to the membership of the Legion of Honor. Those who will achieve this status in 1958 are as follows:

Harry C. Dudley
Duluth, Minn.

A. W. Edelen
Mexico, D. F., Mexico

Donnel F. Hewett
Menlo Park, Calif.

C. Baring Horwood
London, England

George R. Jackson
Ishpeming, Mich.

Michael H. Kuryla
Golden Beach, Fla.

Frank A. Linforth
Butte, Montana

Robert B. Moran
Pasadena, Calif.

Desaix B. Myers
Pasadena, Calif.

H. R. Robbins
Honolulu, Hawaii

Howard L. Smith
Washington, D. C.

Letters from these men give some indication of what membership in AIME for 50 years has meant to them. Some of their comments were:

> "I now feel very happy over the fact that I was able to continue as a member of the Institute for 50 years, during which time my membership in the Institute has been a very happy connection and has been the means of giving me an enormous amount of information."
>
> "I have enjoyed all of my fifty years of membership not only professionally but also for the many happy associations."

George R. Jackson, in a letter expressing his appreciation for the honor, commented, "It may interest you to know that on glancing over the list of members who have been elected to the Legion of Honor I found that the first name—that of Harry C. Dudley—was well known to me, as I gave him his first job after his graduation from school." Others mentioned their pleasure at the inclusion of old friends in this year's class: A. W. Edelen stated that he noted his "good friends Harry Dudley and Mike Kuryla are also of the 1908 Class." Desaix B. Myers mentioned both the value of his membership and old friends:

> "My membership in the AIME has been helpful to me professionally by keeping me abreast of progress in technology, and also because of the many fine associations developed through the Institute. In this regard I am delighted to see that my old friend Bob Moran is a fellow 'classmate' and will receive his Insignia with me."

Members of the 1908 Class, Legion of Honor, have expressed their hope to be able to attend the Annual Banquet at which time formal presentation of the Insignia will be made. The Insignia consists of a gold lapel pin engraved with the man's name and is accompanied by an engrossed certificate.

New York Group Will Visit Nutley Center

The January meeting of the Physical Metallurgy Group, New York Section, will be held on Wednesday, Jan. 15, 1958. The Federal Telecommunication Laboratories in Nutley, N. J., will be hosts to the group on

this occasion. Robert M. Fisher of the U. S. Steel Corp., Monroeville Research Center, will present a talk in the evening on *Applications of Electron Optics in Metallurgical Research.*

The speaker, a physicist from the University of Michigan, has been engaged in the applications of X-ray and electron optical techniques to problems in metallurgy and solid state physics ever since he joined the Kearney (now in Monroeville, Pa.) Research Laboratory of the U. S. Steel in 1949. Part of his work in the past years has been devoted to constructing one of the first electron probe microanalyser to be built in the United States. *Bob* Fisher, the author of 11 papers, is a well recognized authority in this field, having been honored with the chairmanship of the ASTM Subcommittee XI on Electron Microstructure of Metals. At present, he is a director of the Electron Microscope Soc. of America and president of the Pittsburgh Optical and Electron Microscoptical Soc.

The Federal Telecommunication Laboratories are a division of the International Telephone and Telegraph Corp. and boast as the central building of their research center the startling oval tower, which catches all eyes in its attractive parklike surroundings on the bank of the Passaic River in Nutley. The staff of the laboratory, which comprises 2400 people, has arranged several interesting demonstrations which will be shown members who participate in a special tour being arranged for the afternoon. This laboratory employs solid state physicists, electronic engineers, chemists, and mechanical engineers to develop special devices for use in the ever broadening field of communication. As hosts, they are also making arrangements for the dinner which will precede the evening lecture by Robert Fisher in their conference hall.

NOHC Section Meeting Held in Columbus

Close to 200 registrants gathered at the Deshler-Hilton Hotel in Columbus, Ohio, on October 18 for the 21st annual conference of the Southern Ohio Section of NOHC.

Leo Reinartz, one of the most famous steelmakers from that area, opened the meeting by tracing the first century of steelmaking in this country and noting some of the new processes that will be figuring in the next 100 years.

The morning operations session was devoted to a re-evaluation of charging layout and practice. Speakers included R. K. Thornberry, Acme-Newport Steel; R. W. Lewry, Detroit Steel; and T. J. Murray, Tom Burney, Mac Sample, and W. C. Jack, all from Armco. The session was under the chairmanship of O. V. Ireland, Armco; and A. W. Meihack, Empire Steel.

The afternoon session, which had R. K. Thornberry and T. J. Murray as chairmen, was devoted to open hearth practice. C. W. Gravens, Republic Steel, reported on the sprung basic roof, noting that while the cost is higher, advantages of this construction indicate that silica brick is on its way out.

Tom Moore of Armco, speaking on tap-hole maintenance, stressed that proper maintenance would give not only longer life, but also better manganese efficiency. F. E. Williams, also of Armco, spoke on instrumentation and maintenance of bath immersion thermocouples. Important here were education of those using the equipment and careful avoidance of waste of the platinum and other expensive components.

Two special survey reports were presented. The first, on auxiliary equipment maintenance, was given by J. W. Flowers of Armco. Wide diversity seems to be the characteristic for both methods of material movement and maintenance. The other survey report, delivered by Charles Hesselman of Acme-Newport, was on the subject of brick salvage, and noted that savings of $200,000 annually may be saved by large plants using proper salvage methods.

The annual dinner, presided over by M. F. Yarotsky, National Chairman of NOHC, featured David Guy Powers, prominent author and psychologist from Queens College, New York. Dr. Powers, in a talk that was both entertaining and instructive, discussed the problem of getting one's ideas across, stressing that persuasion is only accomplished by letting the other person think the idea is really his own, and that the idea has to be expressed in terms of the person who is to carry it out.

The following day many of the registrants enjoyed the Ohio State—Indiana football game as guests of the suppliers.

The NOHC Southern Ohio Section is under the chairmanship of P. G. Sammet, R. K. Thornberry is vice chairman, and O. W. Morris is secretary-treasurer.

NOHC Eastern Section Holds Annual Meeting

The NOHC Eastern Section held its annual meeting on Friday, October 11, with 302 registrants in attendance. For the first time, this meeting was held at the brand new Sheraton Hotel in Philadelphia. The day's activities included technical sessions in the morning and afternoon, and a dinner in the evening.

After opening remarks by the chairman, C. D. Moore of G. & W. H. Corson Inc., the award-winning paper on *Hot Top Material—A Gas Study in Material Handling* was read by Wallace F. Low at the John A. Roebling's Sons plant of Colorado Fuel and Iron Corp. A panel discussion on *Cutting Steelmaking Costs* was conducted with Harry Davis of Bethlehem Steel Co. as moderator. Participating in the panel discussion were H. W. Potter, Lukens Steel Co.; J. E. Deegen, Bethlehem Steel Co.; Howard Parker, United States Steel Corp.; Nicholas Ivanoff, Harrisburg Steel Corp.; J. A. Petroskas, Phoenix Iron and Steel Co.; Harry Tear, Washburn Wire Co.; and William S. Webb, Colorado Fuel and Iron Corp.

After a group luncheon, the afternoon session was convened by the chairmen, Gardner Blythe of Colo-

(Continued on page 1554)

Southwestern Steelmen Convene in Houston

The Southwestern Section of NOHC met in Houston for the first time in seven years on October 3rd and 4th with an enthusiastic attendance of 225 open hearth engineers from Alabama, Colorado, Illinois, Missouri, Texas, and Mexico. A special train brought delegates from St. Louis, while others descended on Houston's Shamrock Hotel by air and automobile.

Thursday, October 3rd, brought delegates on a tour of the integrated Sheffield Div. plant of Armco. They saw the plant's recently installed ore bedding-sintering plant as well as its open hearth and electric furnace shop, its blooming/slabbing mill, the plate mill, merchant and structural mill, and the wire mill. A southern *chicken fry* was offered by Sheffield on tables spread under moss-covered trees in the 90° sun.

Seven technical papers plus open floor discussion occupied the delegates on Friday. A report was presented on CF&I's oxygen treatment of pig iron as it flows in a runner from the blast furnace. A comparison was made between the open hearth and the electric furnace, their capital and operating costs, as well as their place in the development of the steel industry. A considerable floor discussion of the oxygen lance in the open hearth ensued, and the afternoon session included papers on pouring practice, high pressure gas firing, and a questionnaire on open hearth brick consumption.

A convoy of Greyhound buses awaited conclusion of the session to transport all to the Turning Basin, where delegates boarded a boat for a tour of the Houston port and the ship channel. Firmly anchored by the old warship Texas, a cocktail hour and delicious seafood dinner followed at historic San Jacinto Inn.

The fellowship, technical reports, and Texas hospitality made the meeting a memorable occasion for all.

NOHC Eastern Meeting

(Continued from page 1553)

rado Fuel and Iron Corp., and George Baldwin of Standard Steel works. R. Russell Fayles of Lukens Steel Co. presented a report on *Steel Plants in Europe*. His summary of impressions of some 35 steel plants visited in nine European countries, pointed out the extreme devotion to research of European steel companies and the results of that research in such factors as installation of steam boilers on open hearth furnace doors, prefabricated fronts for tilting furnaces, new *umbrella*-type hot tops in Sweden to cut hot top costs, roof oxygen lances to shorten heat times by one hour, and large basic roof furnaces to counteract the poor quality of European silica-clay bricks.

The second paper, by W. J. Flynn of United States Steel Corp., Gary, described *Contributions of Bath Temperature Control to Improved Open Hearth Production Rates*. By use of a thermocouple taking readings from a spoon immersed in the open hearth bath, complete control of heats making over 0.20 pct C steel can be controlled completely from melt down to tap. These advantages have been obtained: greater fuel economy, increased steel production, better quality steel, and decreased cost of refractories.

The third paper, by H. M. Parker of Armco Steel Corp., Butler, Pa., described *The Use of a Super-Charger* to increase the rate of charging scrap to the furnace. Through use of the Calderon system, scrap is delivered in bulk in a single car replacing eight standard pan cars; the scrap is then lifted by a magnet into a special hopper, through which the scrap passes into a charging pan for delivery to the furnace. Not only can scrap be charged more quickly by this system, but the operation of nearby furnaces is not blocked by the presence of charging buggies.

Ralph Sundstrom, United States Steel Corp., Fairless Hills, Pa., described *The Use of a Continuous Oxygen Analyzer*. Through the development of a sampling system, as well as the analyzer, U. S. Steel has increased production of steel at reduced cost without increasing open hearth capacity. In addition, other benefits have accrued from increased refractory life and better fuel utilization. The final paper on *Rapid Furnace Rebuild* was presented by A. V. Leun, Bethlehem Steel Co.

C. D. Moore presided at the dinner in the evening. In addition to music and entertainment, courtesy of an active suppliers committee chairmaned by R. L. Batteiger, pertinent remarks were made by M. F. Yarotsky, chairman of the National Open Hearth Steel Committee, and by Harry Davis of Bethlehem Steel Co. on *Half a Century of Steel*.

Plans Are Announced For Steel Conferences In Cleveland In April

Advance plans have been made for the combined Conferences for the National Open Hearth Steel Committee and for the Blast Furnace, Coke Oven, and Raw Materials Committee, to be held in Cleveland, Apr. 14 to 16, 1958, at the Statler Hotel.

The Open Hearth Conference will open with a paper on the history of steelmaking by Leo F. Reinartz, a Past-President of AIME, and an organizer of NOHC. On the opening day, papers will be presented on *Charging of Cold Metallics* at the basic operations session, and on sulfur removal and casting technology at the session on acid operations. Other technical sessions will be presented on refractories and masonry, operating metallurgy, cold metal and basic foundry practices, operating and combustion, and a special session organized by the Iron and Steel Division Physical Chemistry of Steelmaking Committee on *Fundamentals of the Basic Oxygen Process*.

The Blast Furnace Conference will open with a *Practice* session with papers on oxygen use in the blast furnace, present trends in design in the blast furnace, on refractories at the stockline, and on high-moisture blast. Other sessions will be held on recent blast furnace developments, raw materials and burden, byproducts, coal preparation, and coke. The concluding session on Tuesday afternoon, April 15, will be a joint session of interest to both blast furnace and coke oven operators and will include papers on iron coke, history of blast furnace over the last forty years, and a panel discussion of effect of blast furnace performance.

The final day of the Conference will feature a trip to the Cleveland Works of Republic Steel Corp. Local arrangements for the joint Conference are being made by Charles W. Cravens, assistant district manager, Republic Steel Corp. Cleveland, as Chairman of the Local Arrangements Committee. The program for the Open Hearth Conference has been developed under the leadership of Michael F. Yarotsky, chairman of the National Open Hearth Steel Committee, and Charles M. Kay, chairman of the Program Committee. The Blast Furnace technical sessions have been arranged by Firm M. Hamilton, chairman of the Blast Furnace, Coke Oven, and Raw Materials Committee, and James B. Wagstaff, chairman of the Program Committee.

PERSONALS

Donald N. Rosenblatt, chief metallurgist for the American Foundry & Machine Co., division of the Eimco Corp. in Salt Lake City, has won top honors in the third product development contest sponsored by the Steel Founders Soc. of America. He received a $1000.00 cash award and a gold certificate for his winning technical paper, *Use of Steel Castings in Mining Equipment*.

Donald L. Colwell has been elected vice president in charge of laboratories and research for Apex Smelting Co., Chicago. Mr. Colwell, who has been associated with the company for 12 years, recently gave a talk on *"Aluminum and Zinc in the Die Casting Process"* at the Chicago chapter of the Soc. of Die Casting Engineers.

Hosur S. Rao is now associated with the Allegheny Ludlum Steel Corp., Watervliet, N. Y.

Frederick A. Sotok has recently been assigned to New York University, New York, for nine months by the U. S. Air Force.

Robert G. Shepheard is now a metallurgical engineer in the R&D Section of Electric Boat Div., General Dynamics Corp., Groton, Conn.

Morris W. Mote is now associated with the Denver Research Institute, University Park, Denver.

Sheldon Weinig, formerly assistant professor at New York University, New York, has joined the Materials Research Corp., Yonkers, N. Y.

Allen E. Martin is now employed by the chemical engineering div. of the Argonne National Laboratory, Lemont, Ill.

E. Saaremaa is currently working for the Aluminum Laboratories in Kingston, Ontario.

J. R. Suazo has joined the Chino Mines Division in Hurley N. M.

J. M. Short is now serving in the Mat/Oils Section, Engineer-in-Chief's Dept., Admiralty, Foxhill Bath, England.

James Lommel is now assciated with the General Electric Research Laboratory, Schenectady, N. Y. Mr. Lommel was formerly with the Gordon McKay Laboratory, Harvard University, Cambridge, Mass.

John R. Perkins has been appointed assistant to the president in charge of market development for McDowell Co. Inc., Cleveland.

Anton F. Mohrnheim, previously with Leach & Garner Co., Attleboro, Mass., is now associated with

the College of Engineering, University of Rhode Island, Kingston, R. I.

L. W. Moore has been appointed assistant general manager of Wheeling Steel Corp's. Stubenville, Ohio, works. He formerly was assistant to the general manager, utilities and development.

Gustave Laub, vice president and director of Vandium Corp. of America, New York, is now administrating and coordinating the activities of the company's selling and technical divisions dealing with commercial affairs.

Lee F. Weitzenkorn, formerly Armco Steel Corp.'s works metallurgist at the Baltimore Works, has now been promoted to assistant to the works manager. Mr. Weitzenkorn will coordinate the steel works quality control and develop improved processing procedures. **John S. White,** formerly supervising metallurgist, becomes works metallurgist.

OBITUARIES

Kenneth N. Baker (Member 1956), manager of Hercules Powder Co.'s explosives department sales office, died in Birmingham on October 16. A native of Nokomis, Ill, he was a graduate of Illinois College and Columbia University. Mr. Baker joined Hercules in 1942 at Radford Arsenal, Radford, Va., and served there and at Sunflower Ordnance Works, Lawrence, Kan., for the duration of World War II. He served on the Hercules sales staff at Pittsburgh and at Wilmington, Del., prior to his assignment as assistant manager at Birmingham in 1956. Mr. Baker became manager of the Birmingham office in April 1957.

Verne H. Schnee (Member 1950) died in Washington on September 22. A metallurgist and government adviser on defense materials, he had served for the past eight years as executive director of the Materials Advisory Board of the National Academy of Science-National Research Council. A native of Cleveland, Mr. Schnee attended Cornell University and was a Welsbach Fellow with the U. S. Bureau of Mines in 1921. After a period in teaching at Cornell and some years in private industry, he became assistant director of Battelle Memorial Institute and director of the University of Oklahoma Research Institute. He was vice president of the University prior to entering Government service. During World War II, Mr. Schnee was chairman of the Products Research Div., NAS-NRC War Metallurgy Committee, and acted as a consultant to other war production and development agencies. He had also served from 1943 to 1946 as chairman of the NRC Committee on Ship Construction.

Paul D. Merica (Member 1918), an Honorary Member and former Vice President and Director of AIME, died on October 20 in Tarrytown, N. Y. He had retired as president of the International Nickel Co. of Canada Ltd. in April 1954 but had continued to serve the company on important projects and as consultant to the officers. Born in Warsaw, Ind., in 1889, he attended De Pauw University, the University of Wisconsin, and the University of Berlin. Mr. Merica had been associated with the metallurgical division of the U. S. Bureau of Standards before beginning his long career with Inco in 1919. He served in a succession of positions before becoming president of the Canadian firm in 1952. His many contributions in the field of metallurgy brought him honors during his career, among them the AIME James Douglas Medal, the John Fritz Medal, the Institute of Metals Medal, the Franklin Institute Medal, and the ASM Gold Medal. Mr. Merica was the recipient of honorary degrees from De Pauw University, Lehigh University, and Stevens Institute of Technology.

MEMBERSHIP

Proposed for Membership
Metallurgical Society of AIME

Total AIME membership on Oct. 31, 1957, was 28,492; in addition 3,343 Student Members were enrolled.

ADMISSIONS COMMITTEE

Harold K. Work, Chairman; Francis B. Foley, T. D. Jones; E. S. Machlin; J. H. Scaff; Paul Von Stein; T. B. Winkler.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

Members

J. Robert Behrman, Conshohocken, Pa.
Elmer W. Belka, Salt Lake City
William E. Blatz, Troy, N. Y.
Adam Philip Bunk, Chicago
Charles A. Erickson, Magna, Utah
George Fegan, Spokane
John K. Hastings, Eggertsville, N. Y.
Kenneth B. Highie, Wyomissing, Pa.
Robert P. Hightower, Benham, Ky.
Richard R. MacFarlane, Cohoes, N. Y.
Edgar W. Sniffen, Chicago
Augusto Vasquez M., La Oroya, Peru
S. Edward Wolosin, Lebanon, Pa.

Associate Members

Lee R. Dobler, East Helena, Mont.
J. N. Geopfarth, Salt Lake City
Stanley R. Joy, Salt Lake City
Francis T. M. Loud, Birmingham, Mich.

Junior Members

James C. Banks, Youngstown
Howard Bardwell, Tooele, Utah
Emil L. Bereczky, Cleveland
Conrad B. Fredericks, Columbia Falls, Mont.
Donald J. Irvine, Toronto
Donald R. Johnson, Chicago
Howard T. McHenry, Watervliet, N. Y.
David S. Morgan, Longview, Wash.
Francis L. Muscatell, Green Island, N. Y.
Everett A. Parker, Albany
David Pezdirtz, Columbus, Ohio

CHANGE OF STATUS

Associate to Member

Moss V. Davis, Birmingham
Kay K. Ikeuye, Sunnyvale, Calif.
Robert C. Peterson, Danbury, Conn.
Earl C. Sutherland, Alma, Mich.

REINSTATEMENTS

Members

Andre Hone, Quebec

REINSTATEMENT—CHANGE OF STATUS

Student to Member

H. W. Higgs, La Oroya, Peru

Student to Junior

Henry M. Butler, Watervliet, N. Y.

NECROLOGY

Date Elected	Name	Date of Death
1956	Kenneth N. Baker	Oct. 16, 1957
1957	Theodore W. Becker	Aug. 16, 1957
1951	John Wesley Braden	Unknown
1941	Erle P. Halliburton	Oct. 13, 1957
1916	H. J. Rahilly	July 25, 1957
1950	Verne H. Schnee	Sept. 22, 1957
1942	John W. Thompson	Sept. 22, 1957
1918	Paul D. Merica Honorary Member	Oct. 20, 1957

PROFESSIONAL SERVICES

Limited to AIME members, or to companies that have at least one AIME member on their staffs. Rates $40 per year per inch.

ALLOY METAL PRODUCTS, INC.
Consultants
Metallurgical by product, scrap and waste utilization.
Rockingham Road — Davenport, Iowa

H. L. TALBOT
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Extraction and Refining of Base Metals Specializing in Cobalt and Copper
Room 911, 209 Washington St. Boston 8, Mass.

MAX STERN
Consulting Engineer
Expert for Scrap Recovery and Shipwrecking—Modernization of Plants and Yards for Ferrous and Nonferrous Metal Scrap
10 East 40th St. New York 16, N. Y.

DR. E. TSUTSUMI
Registered Japanese Patent Attorney & Consulting Engineer
PATENT MATTERS handled . . . TECHNICAL TEXT translated from Japanese into English or vice versa: 2¢ an English word.
Central P.O. Box 1545 — Tokyo, Japan

COMING EVENTS

Dec. 4-6, AIME, 15th Electric Furnace Steel Conference, Penn-Sheraton Hotel, Pittsburgh.

Dec. 11, AIME Powder Metallurgy Group, New York Section, dinner meeting, Brass Rail Restaurant, New York.

Dec. 11, AIME San Francisco Section, Christmas party, Engineers' Club, San Francisco.

Dec. 12, AIME Utah Section, Salt Lake City.

Dec. 13, AIME St. Louis Section, ladies' night, Hotel York, St. Louis.

Jan. 8, 1958, AIME San Francisco Section; speaker: W. T. Griswold; subject, *Pima;* Engineers' Club, San Francisco.

Jan. 10, AIME St. Louis Section, joint meeting with AIChE St. Louis Section, Hotel York, St. Louis.

Jan. 15, AIME New York Section, Physical Metallurgy Group, plant trip to Federal Telecommunication Laboratories, Nutley, N. J.

Jan. 16, AIME Cleveland Section, annual meeting and ladies night; speaker: J. W. Robb; subject: *Curious Patents;* Carter Hotel, Cleveland.

Jan. 16, AIME Utah Section, panel discussion: *Industrial Engineering Practices in the Mineral Industries;* moderator: I. K. Hearn, Salt Lake City.

Jan. 22, AIME Niagara Frontier Section, election of officers, Red Coach Inn, Niagara Falls, N. Y.

Jan. 28, AIME Connecticut Section, Bridgeport meeting, University Club, Bridgeport, Conn.

Feb. 13, AIME Cleveland Section, Carter Hotel, Cleveland.

Feb. 16-20, AIME Annual Meeting, Statler and Sheraton-McAlpin Hotels, New York.

Mar. 12, AIME New York Section, Powder Metallurgy Group, Brass Rail Restaurant, New York.

Mar. 17-21, EJC Nuclear Congress, International Amphitheatre, Chicago.

Apr. 14-16, AIME, 41st National Open Hearth Steel and Blast Furnace, Coke Oven, and Raw Materials Conference, Hotel Statler, Cleveland.

May 5-6, AIME, Conference on Properties of High-Strength Steel, Penn-Sheraton Hotel, Pittsburgh.

May 5, 6, AIME High-Temperature Materials Conference, Ambassador Hotel, Los Angeles.

May 12-16, Southwestern Metal Exposition and Congress, State Fair Park, Dallas.

May 27-29, AIME Third Reactive Metals Conference; host section: Niagara Frontier Section; Statler Hotel, Buffalo.

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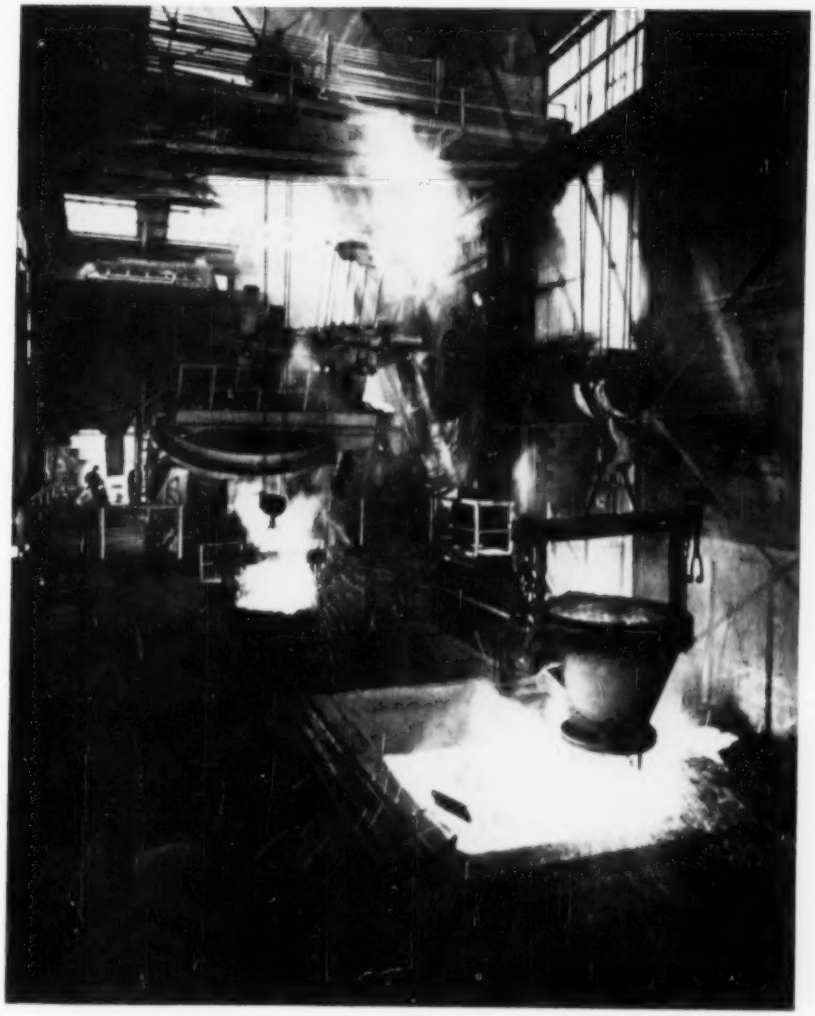

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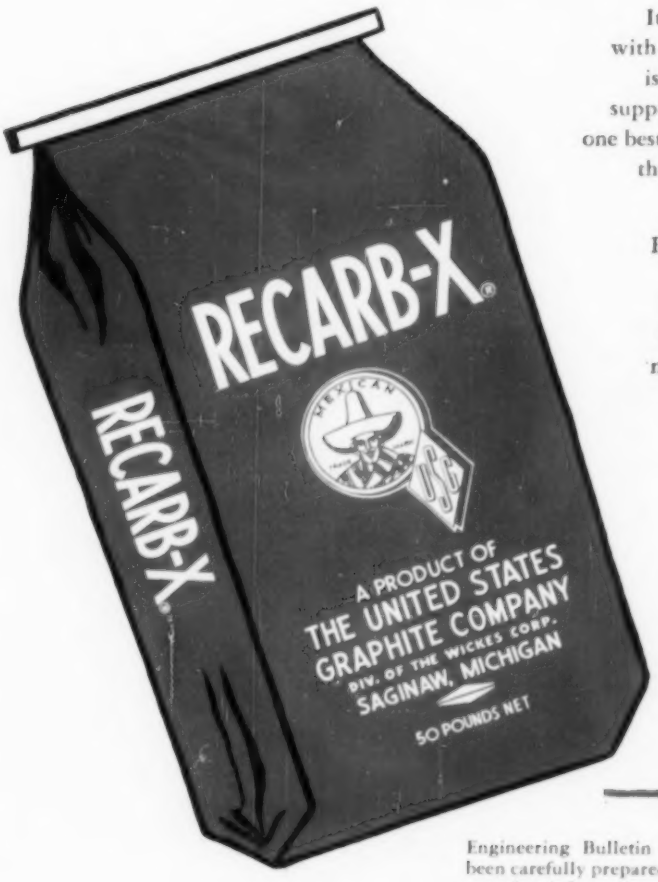

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